

SENN. (N.)

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AN EXPERIMENTAL CONTRIBUTION TO
INTESTINAL SURGERY

—:— . WITH SPECIAL REFERENCE TO THE —:—
TREATMENT OF INTESTINAL OBSTRUCTION.

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READ IN THE SURGICAL SECTION OF THE NINTH INTERNATIONAL MEDICAL CONGRESS, WASHINGTON, SEPTEMBER 5, 1887.
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By NICHOLAS SENN, M. D., PH. D.,

OF MILWAUKEE.

ATTENDING SURGEON TO THE MILWAUKEE HOSPITAL, PROFESSOR OF THE PRINCIPLES OF SURGERY AND SURGICAL PATHOLOGY IN RUSH MEDICAL COLLEGE, CHICAGO, ILL.

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J. H. CHAMBERS, & CO., 914 LOCUST ST.,
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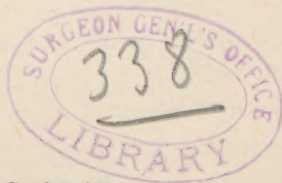
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AN EXPERIMENTAL CONTRIBUTION TO INTES-
TINAL SURGERY WITH SPECIAL REFER-
ENCE TO THE TREATMENT OF
INTESTINAL OBSTRUCTION.¹

BY NICHOLAS SENN, M.D., PH.D.,

OF MILWAUKEE.

ATTENDING SURGEON TO THE MILWAUKEE HOSPITAL, PROFESSOR OF THE PRINCIPLES
AND PRACTICE OF SURGERY AND CLINICAL SURGERY IN THE COLLEGE OF
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THE most important, and, at the same time, the most popular topic for discussion among surgeons of the present day is intestinal surgery. The current medical literature is teeming with reports of cases, and at the meetings of almost every medical and surgical society, large or small, this subject comes up for discussion and occupies a liberal space and conspicuous place in their printed transactions. The unusual activity which has been manifested in all parts of the civilized world in the development of this, one of the most modern and aggressive departments of abdominal surgery, is sufficient evidence that the subject is comparatively new, and as yet imperfectly understood. A study of the literature of intestinal surgery must convince every unprejudiced mind that here, as in many other difficult problems in surgery, the positive knowledge which we have acquired rests almost exclusively on the results obtained by experimental research. Gunshot wounds of the abdominal cavity have been made the object of careful and patient experimentation by a number of enthusiastic surgeons, and the results obtained have laid the foundation

¹Read in the Surgical Section of the Ninth International Medical Congress, Washington, September 5, 1887.

for a rational method of treatment of these injuries, which has been eagerly accepted by all modern aggressive and progressive surgeons. The practical results which have been obtained thus far in the hands of a number of surgeons have been the means of saving a number of lives, which by the old conservative method of treatment would have been doomed to inevitable death from hæmorrhage or septic peritonitis. The numerous valuable practical suggestions for treatment of gunshot injuries of the intestines are the direct outcome of experiments on animals, and this, as well as the remarkable recoveries following gunshot wounds of the abdomen treated by laparotomy, have so firmly convinced the profession of the necessity of resorting to operative measures in such cases that few surgeons could be found at the present day who would be willing to trust to conservative treatment any case where positive, or only probable, evidences pointed towards the existence of a visceral injury of any portion of the intestine. While a decided advance has been made in the treatment of injuries of the intestinal tract, the operative treatment of intestinal obstruction still constitutes one of the darkest and most unsatisfactory chapters in the wide domain of intestinal surgery. The obscurity and uncertainty which cling to this subject are due to the difficulties which often surround an accurate diagnosis. At the same time we have every reason to believe that the appalling mortality which has so far attended the surgical treatment of intestinal obstruction is mainly due to late operations, and not infrequently to a faulty technique in the removal of the cause of the obstruction, and in the restoration of the continuity of the intestinal canal. An accurate anatomical or pathological diagnosis in such cases during life is often difficult, if not impossible, and when, as a *dernier ressort*, laparotomy is performed, and the surgeon is confronted by an unexpected condition of things, he is often in doubt as to what course to pursue, and frequently ends the operation by establishing an artificial anus. No one who has been forced to resort to this measure has left his patient with a feeling of satisfaction, as he must have been sadly impressed with the fact, that, at best, he has only been instrumental in relieving the urgent symptoms of the obstruction, while he has failed to re-

move its cause, and consequently also in restoring the continuity of the intestinal canal. A patient with an artificial anus is indeed an object of commiseration, as experience has sufficiently demonstrated how difficult it is in many instances to close the abnormal outlet, even after the cause of obstruction is subsequently removed or corrected spontaneously, without exposing him a second time to the risks of life incident to another abdominal section. If the causes which have led to the obstruction are of a permanent character, all attempts at closing the fistulous opening will, of course, prove worse than useless, and the patient is condemned to suffer from this loathsome condition the balance of his or her lifetime without a hope of ultimate relief. I believe I can safely make the statement without fear of contradiction that most of these unfortunate patients would prefer death itself to such a life of misery. The ideal of an operation for intestinal obstruction embraces the fulfilment of two principal indications:

1. The removal or rendering harmless of the cause of obstruction.
2. The immediate restoration of the continuity of the intestinal canal.

To meet the first indication the cause of obstruction must be found, its nature determined, and whenever advisable or practicable, it is removed, a step in the operation which may be very easy, or may demand a most formidable and serious undertaking, more especially in cases where the pathological conditions which have given rise to the obstruction are of such a nature as to constitute in themselves an imminent or remote source of danger, as, for instance, malignant disease or gangrene of the bowel from constriction. In all cases of inoperable conditions the cause of obstruction is rendered harmless as far as obstruction is concerned by establishing an anastomosis between the bowel above and below the obstruction by an operation which will be described further on.

Immediate restoration of the continuity of the intestinal canal should be secured in the operative treatment of all cases of intestinal obstruction, with the exception of inoperable cases of carcinoma of the rectum, but is most urgently indicated in cases of obstruction in the upper portion of the small

intestines and the colon, as the formation of an artificial anus in the former locality would prove a direct source of danger from marasmus by excluding too large a surface for intestinal digestion and absorption, while in the latter situation the cure of a fæcal fistula only too often proves an opprobrium of surgery. A careful perusal of the literature on the treatment of intestinal obstruction proves only too plainly the imperfection of this branch of surgery. The rules laid down in our text-books are often given with so much hesitation that it becomes impossible to apply them in practice. Opinions are so widely at variance that every surgeon finally acts upon the impulse of the moment and adopts a method which he deems appropriate for his case. It can be said that no uniformity of action exists, consequently the statistics which have been produced so far are of but little value from a practical standpoint. A rational and successful surgical treatment of intestinal obstruction, like other abdominal operations, can only be established upon a basis founded upon the results obtained by experimental investigation. In view of this fact it is astonishing that so little has been accomplished in this direction. I am convinced that accurate work of this kind will render essential information in the diagnosis of the obscure causes of obstruction, and will point out more clearly the indications for operative interference, while improved methods of operation will have to be studied exclusively in this manner. During the last 18 months I have made 150 operations on animals for the purpose of studying the effects of the principal varieties of intestinal obstruction, which were produced artificially; at the same time I have attempted to establish a number of new operations for the relief of certain forms of intestinal obstruction where it is impossible or inadvisable to remove the local conditions which gave rise to the obstruction. One of the greatest dangers in all operations for intestinal obstruction is the length of time required to perform the ordinary operations: hence it has been my object to simplify the operations, and thus by shortening the time diminish the danger from shock. All patients requiring an operation for intestinal obstruction are invariably in a condition not well adapted for prolonged operations, which necessitate the opening of the peritoneal

cavity and exposure of its contents to the cooling influences of the atmospheric air. An operation which can be completed in twenty minutes must certainly prove less disastrous to the patient than one requiring from one to two hours. A prolonged operation on the intestines is attended by two great risks: (1). Immediate, due to shock. (2). Remote, prolonged exposure to infection. Both of these dangers are diminished in proportion to the shortening of the time consumed in the operation, which is made possible by resorting to simpler measures, provided they are equally safe and efficient.

GENERAL REMARKS ON EXPERIMENTS.

With few exceptions the experiments detailed in this paper were made at the Milwaukee County Hospital, located at Wauwatosa, six miles from Milwaukee. I wish on this occasion to return my thanks to Dr. M. E. Connel, superintendent of the hospital, and his assistants, as well as to Dr. William Mackie, of this city, for valuable services rendered in my experimental work. As the main object of these experiments was not to show favorable statistics, but more for the purpose of studying the effect of different forms of intestinal obstruction and to establish new principles of treatment, the animals were not submitted to any special treatment before or after the operation; the diet was not restricted and no internal medicines were given. I pursued this course in order to bring the intestinal canal in the most unfavorable conditions for operative interference, so as to expose the operations to the severest test. Ether was used exclusively as an anesthetic. The abdomen was shaved, thoroughly washed with soap and warm water, and disinfected with a 1-1000 solution of corrosive sublimate or a two and a half per cent solution of carbolic acid. For the sponges the same solution of carbolic acid or a weaker solution of corrosive sublimate were used. The abdomen was covered by several layers of aseptic gauze, with a slit in the centre. Whenever division or incision of the bowel was made fæcal extravasation was guarded against by compressing the bowel on each side by compressors made for this special purpose, or by constriction with an elastic rubber band. Experi-

ence showed that the latter method was preferable, as it proved less injurious to the tissues of the bowel, and afforded greater security against extravasation, while at the same time it proved less disastrous to the circulation between the points of compression. The rubber bands for this purpose should be about an eighth of an inch in width, rendered properly aseptic by prolonged immersion in a five per cent solution of carbolic acid, and can be readily applied by perforating the mesentery with an ordinary hæmostatic forceps at a point not supplied with visible blood vessels, and tied in a loop with sufficient firmness to obstruct the lumen of the bowel. Elastic constriction practiced in this manner prevents all possibility of extravasation, and does not interfere with the free manipulations of the operator, as is the case with clamps or the hands of an assistant, while the degree of compression that is necessary exerts no injurious effects on the vessels and tissues at the seat of constriction. Drainage was never resorted to, and the abdominal wound was always closed by deep interrupted sutures including the peritoneum. In all cases where partial or complete exventeration was made necessary the bowels were kept covered with warm gauze compresses. In all cases where complete exventeration became necessary, and where the bowels remained out of the abdomen for half an hour or more, a certain degree of shock was always noticed, and a number of animals died within a few hours after the operation, death being referable directly to this cause. For an external dressing we used iodoform ointment applied directly over the wound, and a compress of cotton, retained by a bandage, and a jacket, made of coarse cloth. As a rule the sutures were removed at the end of six days, when the wound was usually found healed by primary union.

I.—ARTIFICIAL INTESTINAL OBSTRUCTION.

In imitation of the more common forms of intestinal obstruction in the human subject, due to congenital malformation or pathological conditions, the following kinds of obstruction were produced on animals: (1) stenosis, (2) flexion, (3) volvulus, (4) invagination. It is a noteworthy fact that even in

cases where the obstruction was complete from the beginning, vomiting was moderate, and in some instances entirely absent. As vomiting constitutes one of the earliest and most conspicuous and persistent symptoms in most cases of intestinal obstruction in men, we can only explain its lesser intensity or complete absence in animals from the circumstance that animals suffering from this condition, as a rule, refuse all food and drink. As a rule, the tympanitis was also less marked than in the human subject.

I. STENOSIS.

Circular narrowing of the lumen of the bowel was produced by excision of a semi-lunar piece of the intestinal wall and double suturing of the wound in a direction parallel to the intestine; and (2) circular constriction with bands of aseptic gauze.

A.—PARTIAL ENTERECTOMY.

Experiment 1.—Dog, weight 39 pounds. A semi-lunar portion embracing half the circumference of the bowel removed from the convex surface, two inches above the ileo-cæcal valve. Wound closed in a longitudinal direction by Czerny-Lembert suture. The first two weeks the discharges from the bowels were fluid and dark in color, subsequently normal in color and consistence. Animal killed 36 days after operation. Body well nourished; abdominal wound indicated by a firm linear cicatrix. Omentum adherent at point of operation; lumen of bowel at point of operation reduced one-half in size; lumen of bowel above and below the contraction equal in size, showing that the stenosis had not furnished an obstacle to the passage of intestinal contents. A few of the sutures remain attached, their free ends floating in the bowel.

Experiment 2.—Large, full-grown cat. The same operation was performed on the concave side of the bowel about the middle of the ileum, a semi-lunar piece of the wall of the intestine with the corresponding mesentery being removed and the wound closed in a similar manner, which diminished the diameter of the lumen of the bowel to about one-eighth of an inch. It was noticed during the operation that the convex surface of the bowel over an area corresponding to the partial excision presented a cyanosed appearance. The animal died

on the fourth day after operation, and the whole segment of the sutured bowel was found gangrenous, but no fluid in the abdominal cavity.

Experiment 3.—Adult, large cat. In this case a segment of the ileum was emptied of its contents, and before cutting away a semilunar piece from the convex surface, a back-stitch, continuous suture was applied on the inner margin of the proposed line of incision, which left about one-third of the lumen of the bowel. After excision of the semilunar piece the margins of the cut surface were turned inwards and covered with serous surface by a continuous catgut suture. Several small passages occurred after the operation, but the animal died on the fourth day with symptoms of intestinal obstruction. The visceral wound was found healed, but the lumen had become so narrow from the inflammatory swelling of the tunics of the bowel that it was entirely inadequate for the passage of intestinal contents, and as a result of this obstruction the bowel had become considerably dilated above the point of operation.

REMARKS.—These experiments illustrate conclusively that in wounds of the convex side of the intestine, where from the nature of the injury transverse suturing is impossible, longitudinal approximation and suturing can be safely done, provided, at least, one-half of the lumen of the bowel can be preserved. If the stenosis is carried beyond this point there is great danger that the inflammatory swelling following the operation will still further narrow the tube and lead to the most serious consequences due to intestinal obstruction, and place the visceral wound in the most unfavorable condition for the healing process.

Experiment 2 shows the great danger of interference with the blood supply from the mesentery in longitudinal suturing of wounds on the concave side of the bowel, as such a procedure is invariably followed by gangrene of the corresponding segment of bowel on the convex side.

B.—CIRCULAR CONSTRICTION.

The following experiments were made to study the effect of circular constriction upon the circulation of the isolated constricted loop of bowel. In all cases where the constriction

was made with a gauze band this was tied with the same degree of firmness, so as to determine whether the same degree of strangulation would produce identical results.

Experiment 4.—Adult cat. A loop of bowel about the middle of the ileum, six inches in length, was tied with a band of aseptic gauze with sufficient firmness to cause slight congestion, but without interfering with a free arterial supply, as the arteries in the ligated portion continued to pulsate freely. The day after operation a few, small fæcal discharges stained with blood. The cat died 48 hours after the operation. No rise in temperature was observed, and death was evidently caused by collapse from perforation. The loop of bowel showed gangrene on convex side equidistant from the point of strangulation, and a small perforation which had given rise to diffuse septic peritonitis. The whole visceral and parietal peritoneum were uniformly affected and the peritoneal cavity contained a considerable quantity of sero-sanguinolent fluid.

Experiment 5.—Large, adult cat. A loop of the ileum of the same length was tied in a similar manner and with same degree of firmness. The animal absolutely refused food until the eighth day. Rise in temperature second and third day. Only one fæcal discharge on the second day. Killed eight days after operation. Abdominal wound completely united; no peritonitis. Four inches of bowel below the point of constriction showing that partial reduction had taken place. The gauze band was found completely covered with adherent omentum, and a thick layer of plastic lymph which formed a complete bridge connecting the intestine above and below the ligature. The ligated portion showed no evidence of defective circulation, and no ulceration underneath the ligature. The obstruction was complete as no fluid could be forced through the bowel, and in proof that the same condition existed during life, it was found that the bowel above the constriction was considerably dilated, while below the strangulation it was empty and contracted.

Experiment 6.—Large, Maltese cat. A loop of the ileum, six inches in length, tied in a similar manner. On the third day fæces stained with blood. On the same day the temperature, which had remained nearly normal until this time, rose to 105° F., and on the following day the animal died, having manifested symptoms of perforative peritonitis for 24 hours. Abdominal wound united; recent diffuse peritonitis. The abdominal cavity contained several ounces of sero-purulent fluid. Bowel above constriction distended with fluid contents, below the ob-

struction empty and slightly contracted. The greater portion of strangulated loop was found gangrenous and adherent to adjacent loops of bowel. Perforation had taken place in the middle of the loop on the convex surface, showing that gangrene had taken place first at this point and had extended from here towards the ligature.

Experiment 7.—Adult dog, weight 26 pounds. In this case an opening was made in the mesentery through which a loop of the small intestine, six inches in length, was pushed. With sutures this opening was made sufficiently small so that its margins produced slight strangulation. The dog remained perfectly well after the operation, and was killed on the twenty-second day. Abdominal wound completely healed. No signs of peritonitis. On searching for the seat of obstruction it was found that spontaneous reduction had taken place, the site of perforation in the mesentery being indicated by a recent cicatrix.

REMARKS.—The post-mortem appearances in these cases demonstrate clearly that the gangrene was not produced by the primary mechanical strangulation, but that it depended upon consecutive pathological changes in the loop or its vessels. In experiment No. 5. the primary strangulation was fully as great as in the preceding experiment, and yet gangrene did not take place, and we have positive proof that vascular engorgement in the ligated portion was less intense from the fact that partial reduction took place. In all cases where gangrene resulted, it must not have been from deficient arterial blood supply, but from an obstruction to the return of blood through the veins. If defective arterial blood supply had been the immediate cause of the gangrene, we would have found more constantly gangrene of the entire loop, while every specimen illustrated that gangrene always commenced at a point where the return of venous blood met with the greatest resistance, viz., on the convex surface in the middle portion of the loop. As in cases of hernia, or in any other form of intestinal strangulation, where a firm constricting band surrounds the loop of bowel, the danger of complete strangulation is increased if by the peristaltic action additional portions of the intestine are forced through the ring, and the immediate cause of the gangrene is always referable to obstruction to the return of venous blood which leads rapidly to œdema, complete stasis,

and moist gangrene in that portion where the venous circulation is most seriously impaired. Violent peristalsis under such circumstances always aggravates the existing conditions, and is often the precursor of symptoms of complete strangulation. In such cases opiates act favorably by arresting peristaltic action, and in so doing may avert gangrene by preventing the causes which otherwise would have led to complete venous stasis.

2. FLEXION.

As many instances are on record where flexion of the bowel constituted the cause of intestinal obstruction, this condition was artificially produced in animals either by making a partial enterectomy by removing a wedge-shaped piece from one side of the bowel, or, by bending the bowel upon itself acutely and fixing it in this position with catgut sutures.

Experiment 8.—Dog, weight 60 pounds. A wedge-shaped piece of the wall of the ileum was removed from the concave side with a corresponding portion of the mesenteric attachment, and after arresting the bleeding by tying several vessels with catgut, the wound was closed transversely by two rows of sutures. The excised piece measured one inch at its base, and the apex reached as far as the median line of the bowel. Immediately after excision, the convex portion of the bowel which had become acutely flexed by uniting the wound presented a livid, congested appearance, and after tying of the sutures the cyanosis increased. The area of disturbance of the circulation corresponded to the width of the base of the excised portion. About 14 inches from this place a similar piece was excised from the convex side of the bowel, and the wound closed in the same manner. At this point the flexion was only slight, the mesenteric portion forming the prominence of the curve. On the third day the temperature rose to 105.6° F., and the following day the animal died with symptoms indicative of perforative peritonitis. On opening the abdomen diffuse, general peritonitis was found with numerous adhesions. Gangrene and perforation were found on the convex side directly opposite the first operation. Second visceral wound closed and lumen of bowel at this point somewhat contracted, but permeable to fluids.

Experiment 9.—Large, adult cat. Removed from convex side of ileum a triangular piece measuring one inch at its base and the apex

reaching a little beyond the middle line of the bowel. Wound closed transversely by Czerny-Lembert sutures. After closure of the wound the bowel presented at point of partial resection an obtuse angle, the apex being formed by the mesenteric portion. The stools were bloody the second day after operation. The animal remained in excellent condition until it was killed, 43 days after operation. Adhesions of loops of small intestines to abdominal wound and of omentum and adjacent intestines at point of operation. The extent of flexion was found somewhat diminished, yet the concavity on convex side of bowel was well marked. Size of bowel above and below the operation was equal, showing that the flexion had not acted as a cause of obstruction. On opening the bowel a pouch-like bulging was found on the mesenteric side, which appeared to compensate for the narrowing caused by the artificial stenosis. Two of the deep sutures still remained attached to the inner surface of the bowel.

Experiment 10.—Adult, large cat. In this case a loop of the middle portion of the ileum, four inches in length, was acutely flexed in such a manner that the peritoneal surfaces of the convex side were brought in contact, and in this position the bowel was fixed by a number of fine catgut sutures. No symptoms pointing towards intestinal obstruction were observed, and the animal was killed 16 days after the operation. Wound was found completely united, and no signs of peritonitis. The angle of flexion had somewhat diminished, but otherwise the bowel adherent in position left after operation. The bowel presented no dilatation above nor contraction below the flexion, showing that complete permeability of the canal at the point of flexion was quickly restored.

REMARKS.—The partial excision on concave side of bowel in experiment No. 8 illustrates the danger of suturing wounds in this locality where the blood supply from the mesentery is likewise impaired, as gangrene of the remaining portion of the bowel is almost certain to take place. In all wounds on this side of the bowel more than half an inch in length, there is also another great danger which attends transverse suturing, viz., stenosis, which may become the cause of intestinal obstruction. As the small intestines naturally describe quite a strong curve with the concavity on the mesenteric side, closure of a wound involving this portion of the bowel gives rise to acute flexion which, at least, during the process of healing, must cause more or less obstruction until by yielding of the

opposite portion of the intestinal wall an adequate dilatation of the calibre of the tube has taken place. A considerable portion of the wall on the convex side of the bowel can be removed and sutured transversely until the bowel has been transformed into a straight tube, and a wound an inch in length will make only a slight flexion which furnishes no serious mechanical obstacle to the passage of the intestinal contents. In this connection the question arises: Does simple flexion, even if acute, without diminution of the lumen of the bowel, give rise to symptoms of obstruction? I have made numerous flexions when performing operations for establishing intestinal anastomosis, and in most instances satisfied myself by examination of the specimens that fluids passed them without great difficulty. If the bowel at the point of flexion remains free, certain portions of its wall will yield to pressure of the fluid intestinal contents, and gradually the lumen of the bowel will become restored. If, on the other hand, the entire circumference of the bowel at the point of flexion has become fixed and immovable by inflammatory adhesions or other pathological products, a compensating dilatation becomes impossible and the flexion becomes a direct and serious cause of obstruction.

3. VOLVULUS.

This condition, only another form of flexion, was experimentally produced by rotating a loop of intestine one and a half or two times around its axis and retaining it in this position by a number of fine sutures which were applied in places at the base of the volvulus, where fixation was most required.

Experiment 11.—Dog, weight 12 pounds. A loop of the ileum, eight inches in length, was brought out through a small incision and the tubes turned around their axis twice and the twist maintained by two catgut sutures. The constriction was sufficiently firm to cause considerable venous engorgement in the twisted loop. The dog manifested no unpleasant symptoms after the operation. The specimen was not obtained, as after a few days the dog ran away.

Experiment 12.—Medium-sized adult cat. In this case the volvu-

lus was made by twisting a loop of the ileum, about four inches in length, twice around its axis, and retaining it in this position by a number of fine silk sutures. Vomited several times during the first day. The first three days in taking the temperature in the rectum the thermometer when taken out was bloody. The first two days the temperature was normal, followed by an increase to 104.6° F. and 103.2° F. the two succeeding days, then it became normal. No constipation; appetite good throughout the whole time. Animal killed 22 days after operation. Abdominal wound completely united; no peritonitis. Volvulus remains as after operation, with the exception that where the bowel had been flattened by the twisting it had, at least, partially resumed its tubular form. Serous surfaces where approximated had become firmly adherent at point of constriction, size of bowel considerably diminished. The twisted loop contained liquid fæces. Connecting the specimen with the faucet of a hydrant, water could be forced through, but on increasing the force of the current the peritoneum ruptured extensively in a longitudinal direction to point of partial obstruction.

REMARKS.—These experiments are interesting, inasmuch as the primary constriction produced in making and maintaining the volvulus which was sufficient to cause venous engorgement in the twisted loop must have been only of short duration, the disappearance of the effects of constriction being undoubtedly due to the gradual yielding of the sutured parts, while the faulty axis of the twisted loop was maintained by the sutures the circulation improved and remained in a sufficiently vigorous condition to adequately nourish the most distant portions of the volvulus. While it was found difficult to force fluid through the specimen of a volvulus, during life, propulsion of the intestinal contents by peristaltic action was carried on in a satisfactory manner, as the bowel above the volvulus was not dilated, and contained no abnormal amount of fluid, and the animal manifested no symptoms indicative of intestinal obstruction.

4.—INVAGINATION.

The most frequent, and, from a surgical standpoint, the most important form of intestinal obstruction is invagination.

Leichtenstern and Leubuscher have made careful experimental studies to explain the mechanism and pathological conditions which give rise to this kind of intestinal obstruction, but in the following experiments this part of the subject was ignored, and the invaginations were made by direct manipulation. It was found impossible to make an invagination at any point, as long as the bowel was in a condition of contraction, consequently it was always found necessary to wait until the peristaltic wave had passed by, or to cause relaxation by firm pressure continued for several minutes. Usually, it was found easy to produce an invagination of the bowel, when in a state of relaxation, by indenting one side of the bowel, and pushing the pouch forward with a blunt instrument until the entire lumen of the intestine had passed into the section of the bowel below. After this was accomplished, further invagination was readily effected by manipulation consisting in pushing gently the intussusceptum and intussusciens in opposite directions. After I had learned by experience that disinvagination frequently takes place spontaneously, I resorted sometimes to suturing of the intussusceptum to the neck of the intussusciens for the purpose of maintaining the invagination. But even this expedient did not always succeed in retaining the malposition, as spontaneous reduction was observed in several of these cases.

Experiment 13.—Adult cat. The lower portion of the ileum and the cæcum and upper portion of the colon were drawn forward into an incision through the linea alba, and 5 inches of the ileum were pushed into the colon through the ileo-cæcal valve, when the parts were replaced and the abdominal wound closed. For six days the animal had a temperature from 102.6° to 105° F. and suffered from tenesmus. The stools contained mucus and blood. After the sixth day the symptoms due to invagination subsided, and were replaced by symptoms of peritonitis. The animal was killed 22 days after operation. Great emaciation; abdominal wound completely united; diffuse purulent peritonitis. The disease had evidently commenced in the ileo-cæcal region, as at this point the pathological changes were found most advanced. Complete spontaneous reduction of the invagination; colon greatly distended, and intensely congested.

Experiment 14.—Large, adult cat. Invagination was made in the lower part of the ileum. Length of intussusceptum three inches. For nine days the scanty fæcal discharges contained mucus and at times blood. On the ninth day the temperature registered 105° F.; absolute refusal of food, and only occasional vomiting; death on the thirty-third day after invagination. Abdominal wound healed; small ventral hernia; no peritonitis. Apparently, the greater portion of the intussusceptum had disappeared by sloughing, and the subsequent healing process had produced an acute flexion at the neck of the intussusciens. Firm adhesions between peritoneal surfaces in the concavity of the flexion, nearly an inch in length. Above this point the intestine enormously dilated and distended with fluid contents. Below the obstruction the bowel was found contracted and empty. Water could not be forced through the obstruction from either direction. On slitting open the bowel in a longitudinal direction it was found that the lumen at the point of flexion was contracted to such an extent that only a fine probe could be passed. On the concave side of the flexion the mucous membrane presented a prominence marked by a number of longitudinal ridges. These folds had undoubtedly acted like valves in completely preventing the passage of intestinal contents, and later of the injection of water. Death in this case resulted from intestinal obstruction caused by cicatricial contraction after the sloughing of the invaginated portion of the bowel.

Experiment 15.—Adult cat. Two inches of the ileum were invaginated into the colon and fixed by two fine silk sutures at the neck of the intussusciens. For two days after the invagination the stools were scanty and contained mucus and blood. On the third day the abdominal cavity was re-opened by an incision along the outer border of the right rectus muscle, and the invaginated bowel drawn forward into the wound. No peritonitis. The bowel at point of operation was very vascular, and the neck of the intussusciens covered with plastic exudation. The sutures were removed and the rectum and colon distended with water for the purpose of effecting reduction. As soon as the colon had become thoroughly distended the adhesions gave away with an audible noise, and complete reduction followed in such a manner that the portion last invaginated was first reduced. After reduction had been accomplished the injection was continued to test the competency of the ileo-cæcal valve. As soon as the cæcum was well distended the fluid passed readily through the valve into the small intestines, showing that the valve had been rendered incompetent by the invagination. The force required to overcome the adhesions in

the reduction of the invagination was sufficient to rupture the peritoneal covering of the large intestines in three different places, the rents always taking place parallel to the bowel. The animal died on the following day with symptoms of diffuse peritonitis.

Experiment 16.—Ascending invagination in a cat. A few inches above the ileo-cæcal region the ileum was invaginated in an upward direction to the extent of two inches. At the time the invagination was made the intussusciptions contracted firmly. In consequence of this a tear occurred in its peritoneal covering in a direction parallel to the bowel. The stools were few and scanty. On the fourth day the animal died of perforative peritonitis. Abdominal wound not united, but the peritoneal wound closed by omental adhesions. Spontaneous reduction of half an inch of the invagination had taken place. Reduction by traction was found impossible on account of firm adhesions about the neck of the invagination. Recent diffuse peritonitis caused by two perforations, one at the neck of the intussusceptum on mesenteric side, and the other a little to one side of this one and on proximal side of bowel. The perforation resulted from beginning sloughing of the invaginated portion of the bowel. About two inches above the invagination the bowel was acutely flexed towards the mesenteric side by recent firm adhesions. Flexion was undoubtedly caused by circumscribed plastic peritonitis and increased peristalsis.

Experiment 17.—Large, adult cat. Descending invagination of ileum to the extent of two inches in the upper portion of this part of the bowel. Second and third days the scanty discharges from the bowel bloody. Temperature from the second day after operation varied between 103.4° F. and 105.4° F. Death from perforative peritonitis on the seventh day after invagination. Abdominal wound united. Recent diffuse peritonitis from a perforation at the neck of the invagination on the mesenteric side. Gangrene of intussusceptum and partial separation which has again caused a sharp flexion of the bowel at the neck of the invagination. Above the seat of obstruction the bowel dilated and distended with fluid contents, below empty and contracted.

Experiment 18.—Young cat. Invagination of ileum into ascending colon to the extent of three inches. For a week after operation frequent tenesmus followed by mucous discharges mixed with blood. The temperature during this time varied from 102.6° to 105° F. After this the animal improved and was in good condition when killed fourteen days after operation. Abdominal wound united. No omental adhesions or peritonitis. Firm union between the serous surfaces.

No dilatation of bowel above seat of obstruction. Intussusceptum not gangrenous, its lumen about the size of an ordinary lead-pencil. It was found impossible to reduce the invagination by traction or by forcible injection of fluid from below. When the traction was increased the peritoneal surface of the neck of the intussusciens ruptured in a longitudinal direction.

Experiment 19.—Large, adult cat. Six inches of the ileum were invaginated into the colon. Frequent bloody discharges until the third day when the abdomen was reopened and the neck of the intussusciens exposed to sight so as to observe directly the mechanism of disinvagination by rectal injection of water. As soon as the colon was well distended the adhesions at the neck of the intussusciens began to give way, and complete reduction followed, as the adhesions gave away under the pressure from below. The abdominal wound was again closed and dressed in the usual manner. The animal recovered completely from the operation, and was killed twenty-four days after the first operation. Abdominal wound well united. In the ileo-cæcal region numerous adhesions around the portion of bowel which had been invaginated and subsequently reduced.

Experiment 20.—Invagination of colon into colon was commenced about the middle of the bowel and advanced as far as the cæcum. Second day bloody discharges from the bowels. Animal killed five days after operation. External wound united only on peritoneal side. Invagination completely reduced. Localized plastic peritonitis limited to the portion of the bowel which had been invaginated, otherwise peritoneum and intestines in a healthy condition.

Experiment 21.—Invagination of colon into colon to the extent of four inches in a cat. The subsequent symptoms only for a short time indicated the existence of invagination, which after they had subsided were followed by evidence of peritonitis. Death occurred on the nineteenth day after the invagination. Abdominal wound well united; diffuse purulent peritonitis; under surface of diaphragm covered with plastic lymph. Although sought for, no perforation could be found in the disinvaginated bowel, but as the peritonitis appeared to have started at the site of operation, it is probable that infection took place through the parietic walls of the disinvaginated bowel.

Experiment 22.—Same kind of invagination made in a cat as in the preceding case. For two days the stools were frequent, scanty, and contained mucus and blood. After this the animal remained in good condition until it was killed thirty-five days after the invagination. Abdominal cavity showed no trace of inflammation. The invagination

was completely reduced and the entire colon presented a normal appearance.

REMARKS.—With the exception of experiment No. 16, the invagination was always made in a downward direction. In the case of ascending invagination gangrene of the intussusceptum and perforation resulted in death from diffuse peritonitis on the fourth day after partial spontaneous reduction had taken place. In experiments, Nos. 15 and 19, both cases of ileo-cæcal invagination, complete reduction was effected by distention of the colon with water; in the first case the force required to accomplish this result was sufficient to produce multiple longitudinal lacerations of the peritoneal surface of the distended bowel, which undoubtedly were responsible for the death on the following day from diffuse peritonitis; while in the second case no such accident occurred, and the animal recovered, although the abdominal wound was re-opened for the purpose of observing the mechanism of reduction by this method of procedure. In one case of ileo-cæcal invagination, experiment No. 18, the intussusceptum remained *in situ* after the invagination, and became so firmly adherent with the intussusciens that even in the specimen reduction by traction was found impossible. In this case, although the lumen of the invaginated portion barely permitted the introduction of an ordinary lead pencil, no symptoms of obstruction were manifested during life, and the bowel above the invagination was not found dilated after death. In experiment No. 14, the sloughing of the intussusceptum led to cicatricial contraction of the bowel and flexion at site of invagination, conditions which resulted in death from obstruction twenty-three days after invagination. The great danger which attends sloughing of the invaginated portion is circumscribed gangrene and perforation of the intussusciens at the neck, and death from perforative peritonitis, as illustrated by experiments Nos. 16 and 17. Experiment No. 16 illustrates that ascending invagination, should it occur, is not more likely to be reduced spontaneously than the more common form of descending invagination. These experiments also demonstrate conclusively that the danger attending the invagination increases the higher it is located in

the intestinal canal, being greatest when it is situated high up in the tract of the small intestines, and gradually less as the ileo-cæcal region is approached. The ileo-cæcal form is less dangerous as spontaneous reduction is more likely to take place, and gangrene of the intussusceptum, when it occurs, does so after a longer time after firm adhesions about the neck of the intussusciens have formed, a condition which is well adapted to prevent perforation. Of the three invaginations of the colon, experiments, Nos. 20, 21 and 22, complete spontaneous reduction took place in all of them from the first to the fourth day, and in only one of them was the result fatal, in experiment No. 21, where purulent peritonitis, either from infection through the operation wound or, what is more probable, through the damaged wall of the colon occurred, and was the cause of death on the nineteenth day after the invagination. Experiments Nos. 15 and 19, prove both the danger and the utility of distention of the colon in cases of ileo-cæcal and colonic invaginations. As a rule, the longer the invagination has existed the firmer the adhesions, and consequently the greater the danger of relying too persistently on this measure in reducing the invagination. In resorting to this expedient in the reduction of an ileo-cæcal invagination, it is of the greatest importance to relax the abdominal wall completely by placing the patient fully under the influence of an anæsthetic, and to add to the distending force as much as possible by gravitation, the patient should be inverted and the injection should always be made very slowly and with requisite care to prevent rupture of the peritoneal coat by rapid over-distention. When the obstruction is located beyond the ileo-cæcal valve, no reliance can be placed upon this measure, as can be seen from the following experiments made to determine the

PERMEABILITY OF THE ILEO-CAECAL VALVE.

Experiment 23.—While completely under the influence of ether an incision was made through the linea alba of a cat, sufficiently long to render the ileo-cæcal region readily accessible to sight. An incision was made into the ileum just above the valve, and by gently retracting the margins of the wound, the valve could be distinctly seen; water was then injected per rectum, and as the cæcum became well dis-

tended it could be readily seen that the valve became tense and appeared like a circular curtain preventing effectually the escape of even a drop of fluid into the ileum. The competency of the valve was only overcome by *over-distention* of the cæcum which mechanically separated its margins, which allowed a fine stream of water to escape into the ileum. The insufficiency of the valve was clearly caused by great distention of the cæcum. That such a degree of distention is attended by no inconsiderable danger was proved by this experiment, as the cat was immediately killed, and on examination of the colon and rectum a number of longitudinal rents of the peritoneal coat were found.

Experiment 24.—In this experiment, a cat was fully narcotized with ether and while the body was inverted water was injected per rectum in sufficient quantity, and adequate force by means of an elastic syringe, to ascertain the force required to overcome the resistance offered by the ileo-cæcal valve. Great distention of the cæcum could be clearly mapped out by percussion and palpation before any fluid passed into the ileum. As soon as the competency of the valve was overcome, the water rushed through the small intestines, and having traversed the entire alimentary canal issued from the mouth. About a quart of water was forced through in this manner. The animal was killed and the gastro-intestinal canal carefully examined for injuries. Two longitudinal lacerations of the peritoneal surface of the rectum, over an inch in length, were found on opposite sides of the bowel.

Experiment 25.—This experiment was conducted in the same way as the foregoing, only that the cat was not etherized. More than a quart of water was forced through the entire alimentary canal from anus to mouth. The animal was not killed, and lived for eight days, but suffered the whole time with symptoms of ileo-colitis. A post-mortem examination was not made in this case, although the symptoms manifested during life leave no doubt that they resulted from injuries inflicted by the injection. It will thus be seen that in the three cases where fluid was forced beyond the ileo-cæcal valve, in two of them the post-mortem examination revealed multiple lacerations of the peritoneal coat of the large intestines, while the third animal sickened immediately after the experiment was made, and died from the effects of the injuries inflicted eight days later. The injection of water beyond the ileo-cæcal valve in the treatment of intestinal obstruction must therefore be looked upon in the light of a dangerous expedient and should never be resorted to.

II.—ENTERECTOMY.

It still remains an open question to what extent resection of the small intestines can be performed with impunity. It is true that Koeberlé, Kocher and Baum, have successfully removed respectively 2.05m., 160ctm., and 137 ctm. of the small intestine in the human subject, but while two of the patients do not appear to have suffered any ill effects in consequence of the removal of such a large surface for digestion and absorption, in Baum's case death, which supervened six months after the operation, was attributable clearly to marasmus, brought about by the extensive intestinal resection. As in a number of pathological conditions of the intestinal canal, as multiple strictures, gangrene, and multiple gunshot wounds, where the wounds are large and in close proximity, it may become necessary to resort to extensive resection, it becomes an important matter for the surgeon to know how much of the intestinal tract can be removed without any immediate or remote ill consequences.

The immediate danger attending such an operation is the traumatism, which, of course, will be proportionate to the length of the piece of intestine removed, while the remote consequences are due to impairment of the function of digestion and absorption caused by the shortening of the intestinal canal. With the view of obtaining additional light on these important questions the following experiments were undertaken.

Experiment 26.—Dog, weight 22 pounds. Mesentery divided into four portions and tied with catgut, and 30 inches of the ileum from near the ileo-cæcal regions upwards excised and ends sutured together by Czerny-Lembert sutures. Abdominal wound failed to unite, and a copious sero-sanguinolent discharge escaped from it the last day. Death on fifth day from peritonitis. Peritoneal adhesions in abdominal wound only partial: omentum adherent to wound. Intestines firmly adherent to omental stump. Circumscribed gangrene of bowel on convex side at site of operation, Recent diffuse peritonitis caused by perforation.

Experiment 27.—In a cat 12 inches were removed from the middle of the ileum, and the ends united by a double row of sutures, mesenteric vessels tied *en masse* with one catgut suture. The animal never allied from the operation, and died the same night of the shock.

Experiment 28.—Dog, weight 36 pounds. Mesentery tied in several sections with catgut ligatures; ileum divided just above the ileo-cæcal valve and six feet of the small intestines excised, and the ends united by Czerny-Lembert sutures. On the third day the fæcal discharges were bloody. Although the appetite remained good, and the dog was allowed to eat as much as he desired, he lost several pounds in weight during the first week. On the third day the abdominal wound opened as the sutures had cut through and required re-suturing. After this time the wound healed kindly. Three or four fluid fæcal discharges during 24 hours. The character of the discharges remained the same, and several microscopic examinations made at different times revealed the presence of free undigested fat. The dog was kept busy eating most of the time, and although the most nourishing food was furnished, he emaciated to a skeleton. He was killed 161 days after the operation. Marasmus extreme, hardly a trace of fat could be found anywhere in the tissues. Stomach enlarged to three or four times its normal size, and distended with food. A slight thickening of the wall of the gut indicated externally the site of suturing, and the lumen of the bowel at this point was slightly diminished in size. At point of operation a loop of intestine was found adherent and somewhat contracted. The remaining portions of the small intestines, only 45 inches in length, seemed to have undergone compensatory hypertrophy, as the coats were much thickened and exceedingly vascular. At the seat of suturing the mucous membrane presented a slight circular prominence. Pancreas, liver, and spleen were normal in size and appearance.

Experiment 29.—Medium-sized, adult dog. Mesentery tied in several sections, and 8 feet and 2 inches of the small intestines from ileo-cæcal region upwards excised and ends sutured in the usual manner. On the following day the dog vomited, and blood was seen to escape from the abdominal wound. Death three days after operation. The abdominal cavity was filled with fluid and coagulated blood, which on closer inspection was found to have escaped from one of the stumps of the mesentery, where the catgut ligature had slipped off.

Experiment 30.—Scotch terrier, weight 10 pounds. Mesentery ligated in parts with catgut ligatures, and the ileum divided 4 inches above the ileo-cæcal region, and 50 inches of the small intestines excised, and the continuity of the intestinal canal restored by the usual method of suturing. Some difficulty was experienced in suturing as the lumen of the upper end was considerably larger than that of the lower. Until four weeks after the operation the dog, although eating well, seemed to become more and more emaciated. After this time he gained some-

what in weight until killed 47 days after the resection. During the whole time the fæces were either fluid or only semi-solid, and at different times contained free, undigested fat. Appetite most of the time voracious. No adhesions to abdominal wound. Omentum adherent to visceral wound and to bowel. The site of operation is indicated by a slight depression on the surface of the bowel. On palpation a ring-like thickening is felt corresponding to the united ends of the bowel. Bowel above seat of resection somewhat enlarged. On cutting into the bowel the point of union is indicated by a circular prominence of mucous membrane. Nine of the deep sutures were found still attached to the mucous membrane. The entire tract of the small intestines which remains measures only two feet and ten inches in length.

Experiment 31.—Adult maltese cat. The mesentery was tied in five sections with catgut ligatures corresponding to 29 inches of the ileum which was excised. Previous experience in circular enterorrhaphy had satisfied me that perforation is most likely to take place on the mesenteric side of the bowel where on account of the triangular place made by the reflections of the peritoneum the muscular coat is not covered by serous membrane. To obviate this difficulty I secured a continuity of the serous covering of the ends of the bowel before suturing by drawing the peritoneum over this raw surface by a fine catgut suture. The mesentery was detached only to a sufficient extent to apply the second row of sutures. The fine catgut suture to approximate the edges of the peritoneum must be applied near the margin of the divided end of the bowel, so that the knot will not interfere with the accurate coaptation of the serous surface between the deep and superficial row of sutures. This modification of circular suturing was adopted for the first time in this case. Although the animal manifested no untoward symptoms, and the appetite remained good, the marasmus was progressive until the time of killing, 12 days after the excision. Abdominal wound not completely united. Intestinal wound, which was two inches above the ileo-cæcal region, completely healed. The sutured surface was adherent to loop of bowel which caused a sharp flexion. Intestine above this point somewhat dilated and partially distended with fæcal accumulation. Slight contraction of the lumen of bowel by circular bulging of mucous membrane, in which most of the deep sutures remained fixed. The post-mortem appearance points to partial obstruction at point of flexion; remaining portion of small intestines measures only 21 inches in length.

Experiment 32.—Medium sized Maltese cat. Mesentery tied in sections, and 34 inches of the small intestines excised and the divided

ends united in the same manner as in the last case, special care being taken to secure an uninterrupted peritoneal surface for divided ends before suturing. Appetite remained good, but progressive marasmus which appeared at once, continued and proved the direct cause of death 21 days after the excision. Abdominal wound firmly united. No peritonitis, Visceral wound completely united; intestine at site of operation covered with adherent omentum.

EXCISION OF COLON.

Experiment 33.—Large, black cat. The meso-colon was divided in numerous sections, and each part separately tied with a catgut ligature. As the meso-colon was very short, a number of the ligatures slipped off and had to be replaced by fine silk ligatures. The entire colon and about two inches of the lower end of the ileum were excised. As it was found impossible to unite the bowel on account of the deep location of the rectal end, it became necessary to close the distal or rectal end by inverting its margins and applying a continuous suture. An artificial anus was established by stretching the ileæ or proximal end into the abdominal wound. Death from shock a few hours after the operation.

Experiment 34.—Medium-sized dog. Resection of entire colon and three inches of ileum. Meso-colon divided into sections and ligated with silk ligatures. In order to enable circular enterorrhaphy it was found necessary to excise a triangular piece from large distal end, so as to make its lumen correspond to that of the divided ileum. After this was done and the lateral wound closed by two rows of sutures, the ends of the bowel were united in the usual manner. Death from shock six hours after operation.

Experiment 35.—Excision of entire colon and two inches of ileum in a cat. Excision of a triangular piece from distal end to narrow the bowel sufficiently, so that its lumen should correspond to that of the ileum. The ileum and rectum were then united by Czerny-Lembert sutures. The animal never rallied from the prolonged operation, and died of shock two hours later.

REMARKS.—The results of these experiments speak for themselves. In all cases of extensive resection of the small intestines where the resected portion exceeded one-half of the length of this portion of the intestinal tract, where the animals survived the operation, marasmus followed as a constant result, although the animals consumed large quantities of food. In all of these cases defective digestion and absorption could

be directly attributed to a degree of shortening of the digestive canal incompatible with normal digestion and absorption. Only one of these animals (experiment No. 27) died from shock a few hours after operation. Another death resulted from the trauma in experiment No. 39, where fatal hæmorrhage occurred from one of the mesenteric vessels where the catgut ligature became displaced from shrinkage of the included mesenteric tissues. When the vessels of the omentum or mesentery are tied *en masse* there is always danger from this source, and to prevent this accident it becomes necessary not to include too much tissue, and to tie firmly with fine threads of aseptic silk. After I commenced to tie in this manner, I encountered no further difficulty in arresting and preventing hæmorrhage in operations requiring incision of these tissues. Although the large artery running parallel with the bowel where the mesentery is attached was excised in every case with the intestine, gangrene and perforation occurred only in experiment No. 26. The post-mortem appearances after extensive enterectomies indicated that the portion of bowel which remains undergoes compensatory hypertrophy, but as a rule the increased functional activity is not adequate to make up for the great anatomical loss. In all instances where the animal recovered from the operation the discharges from the bowels were frequent, fluid or semi-fluid, and contained undigested food, among other substances, free undigested fat, showing that the intestinal secretions play an important role in the digestion of fat. As an approximate estimate the statement can be ventured that in dogs and cats the excision of more than one-third of the length of the small intestines is dangerous to life, as it is followed by marasmus, which sooner or later results in death. As all three cases of excision of the colon proved fatal from shock in from two to six hours, it can be safely asserted that this operation is impracticable, and is invariably followed by death from the immediate results of the trauma.

PHYSIOLOGICAL EXCLUSION.

As extensive resections of the intestines are always attended by great risks to life from the trauma, I concluded to study

the subject of sudden deprivation of the system of a great surface for digestion and absorption by eliminating or diminishing the cause of death from this source by leaving the intestine, but excluding permanently a certain portion from participating in the function of digestion and absorption, in other words, by resorting to physiological exclusion. These experiments were also made to determine the tissue changes which would take place in the bowel thus excluded, and to learn if under such circumstances accumulation of intestinal contents would become a source of danger as had been feared by the older surgeons. The complete interruption of passage of intestinal contents either by section and closure of the bowel, or by making an intestinal obstruction of some kind, and the restoration of the continuity of the physiologically active portion of the intestinal canal was established by suturing of the proximal end of the high section with the distal end of the lower section, or by implanting the proximal end into the bowel lower down, the intervening portion of the intestinal tract in either case, thus becoming the excluded portion.

Experiment 35.—Large cat, weight 9 lbs. Double division of small intestines, upper section made about eight inches below the pylorus, and the lower three feet lower down; the portion of bowel between these circular sections was closed at both ends, and the continuity of the intestinal canal restored by suturing the open ends in the usual manner. In this way three feet of the small intestines were isolated and completely excluded from the digestive canal. The intervening portion was emptied of its contents as completely as possible before its ends were closed by suturing. The animal died on the fourth day after the operation. A small perforation of the sutured bowel on the mesenteric side was found, otherwise the visceral wound was found well united. The perforation had given rise to diffuse peritonitis which was the immediate cause of death.

Experiment 36.—Dog, weight 32 lbs. The jejunum was divided four feet above the ileo-cæcal region, and the distal end closed. Jejunocolostomy was made by implanting the proximal end into a slit made into the convex side of the ascending colon, large enough to correspond to the circumference of the jejunum. The implanted end was fixed in its position by two rows of sutures. The animal never appeared to rally from the effects of the operation, and died at the end

of the next day. The abdominal cavity was found filled with blood, which must have escaped from a mesenteric vessel from which probably the catgut ligature had slipped. The excluded portion, that is, that portion intervening between the circular section and the point of implantation, was found quite empty of intestinal contents, but slightly distended with gas. Implanted end perfectly retained by sutures and slight adhesions between serous surfaces had already taken place. Death in this case was the result of secondary hæmorrhage.

Experiment 37.—Dog, weight 35 lbs. Divided the ileum just above the ileo-cæcal region, and closed both ends of the bowel. Ileo-colostomy was done by making an incision about an inch and a half in length on concave side of ileum, 44 inches above the division and a similar slit on convex side of ascending colon, and uniting these wounds by Czerny-Lembert sutures, thus excluding from the intestinal circulation 44 inches of the bowel. The day after operation the fæces contained blood. During the progress of the case it is frequently noted that the stools were thin, sometimes liquid. Appetite remained good, and animal was well nourished at the time of killing, twenty-five days after operation. Abdominal wall well united. The omentum and a few intestinal loops adherent to inner surface of wound. The excluded portion contracted to more than one-half of its usual size, atrophic, and not nearly as vascular as remaining portion of intestinal canal, the two blind ends adherent to each other and to adjacent loops. The excluded portion contained in its blind end a few sharp fragments of bone. The new opening between the ileum and colon about the capacity of the lumen of the ileum, surrounded by a prominent margin of mucous membrane, which somewhat resembles the ileo-cæcal valve to which still remain attached about ten of the deep sutures. The coats of both bowels at points of approximation thickened by inflammatory exudation.

Experiment 38.—Young cat. The ileum was divided about 30 inches above the ileo-cæcal region; the distal end closed and proximal end laterally implanted into the convex side of the transverse colon, where it was fixed by a double row of sutures. Before implantation the continuity of the peritoneal surface was procured by drawing the peritoneum with a fine catgut suture over the denuded space left after detachment of the mesentery. Although the animal partook freely of food, progressive marasmus set in, to which the cat succumbed eleven days after the operation. Abdominal wound completely healed. Union of implanted ileum with colon perfect. No peritonitis. Excluded portion empty. Bowel above implantation somewhat dilated.

Experiment 39.—Young, but full grown cat. Physiological exclusion of two-thirds of the small intestines, and the entire colon by division of the small intestines at the junction of the upper with the middle third. Closure of distal end, and restoration of continuity of the shortened intestinal tract by making a jejuno-rectostomy. The implantation was made into the upper portion of the rectum at a point opposite the meso-rectum. Previous to section and suturing, the portion of bowel to be excluded was emptied of its contents. Animal died two days after operation. No peritonitis. Slight adhesions between the serous surfaces of rectum and implanted jejunum; excluded portion empty.

Experiment 40.—The entire ileum was excluded in a cat by dividing the intestine at its junction with the jejunum, closure of distal end and making a jejuno-colostomy by implantation of the proximal end into a slit of the transverse colon at a point opposite the meso-colon. The cat remained in good condition until killed 15 days after operation. No vomiting, and movements from bowels normal. Abdominal wound completely closed; no peritonitis; jejunum at point of implantation firmly united; new opening in colon the size of the lumen of the ileum. Excluded portion empty, contracted and anæmic.

Experiment 41.—Large mastiff. The small intestine was divided six and a half feet above the ileo-cæcal region, the distal end closed, and the proximal end implanted into an incision of the transverse colon large enough to receive it at a point opposite the meso-colon. Suturing was done exclusively with fine silk. For three weeks the dog appeared quite well, ate well, and the discharges from the bowels were normal. From this time the emaciation, which commenced soon after the operation was done, began to increase rapidly, the animal began to refuse food, and died of marasmus 32 days after operation. No peritonitis. Excluded portion empty, and reduced one-half in size; the coats of the bowels very much attenuated, and the vessels hardly half the normal size. Only three feet and five inches of the small intestine remained for physiological action; new opening in colon sufficiently large to permit the introduction of the index finger as far as the first point. On slitting open the colon the point of juncture with the jejunum upon the inner surface is marked by a slight ridge of mucous membrane, which bears a faint resemblance to the ileo-cæcal valve.

REMARKS.—For some reason which I am unable to explain satisfactorily, in animals where the same length of intestine was

physiologically excluded, as in the resection experiments, the appetite never became so voracious and the remaining portion of intestine did not undergo the same degree of compensatory hypertrophy as in the excision experiments. Theoretically, two explanations might be advanced; firstly, in shortening the intestinal canal by resection an extensive vascular district is cut off by ligation of the mesentery, and it is only reasonable to assume that the circulation in the remaining branches of the mesenteric artery would be increased, and consequently the functional activity of the organs supplied by them augmented; secondly, in cases of physiological exclusion by lateral apposition it is possible that at least some of the fluid contents reached the excluded portion from which a certain amount might still have become absorbed. The exclusion was complete or nearly so, hence, we must conclude from the post-mortem appearances, that in nearly every instance, the excluded portion presented an atrophic, contracted condition and was only sparingly supplied with blood vessels. From a practical standpoint these experiments teach us that a limited portion of the intestinal canal can be permanently excluded from the processes of digestion and absorption in proper cases by operative measures without incurring any risk of fæcal accumulation in the excluded part. These experiments demonstrate also that physiological exclusion of a certain portion of the intestinal tract is a less dangerous operation than excision, and that in certain cases of intestinal obstruction, where excision has been heretofore practiced, it can be resorted to as a substitute for this operation in cases where excision is impracticable, or where the pathological conditions which have caused the obstruction do not in themselves constitute an intrinsic source of immediate or remote danger to life. The post-mortem appearances of the specimens of these experiments tend to prove that as long as any of the contents of the intestines reach the excluded portion the peristaltic or anti-peristaltic action in that part is effective in forcing it back into the active current of the intestinal circulation.

III.—CIRCULAR ENTERORRHAPHY.

During my experimental work I became convinced that circular enterorrhaphy as it is now commonly performed is attended by three great sources of danger: 1, Perforation at the junction not covered with peritoneum; 2, the length of time required in performing the operation; 3, too many sutures.

To obviate the danger of perforation at the junction of the bowel not covered by serous membrane, I resorted to peritoneal suturing before uniting the bowel by drawing the peritoneum over the denuded space caused by the limited detachment of the mesentery by a fine catgut suture applied near the free margin of the bowel as described before. This requires but little time, and secures for the whole circumference of the bowel a peritoneal covering, so that after the bowel has been sutured the great rule inaugurated by Lembert (serosa against serosa) has been carried out to perfection. The results showed that this little modification of the ordinary method of suturing yielded more satisfactory results, and should therefore be adopted in all cases where circular enterorrhaphy is done with Czerny-Lembert or Lembert's sutures. Time plays an important factor in determining the results of all operations requiring abdominal section, and this is especially true in all operations for intestinal obstruction, as this class of patients are usually greatly exhausted before consent for an operation can be obtained. With a patient exhausted from an acute attack of obstruction of the bowels, it becomes exceedingly important to consume as little time as possible in the operation, as the shock incident to a long operation may itself determine a fatal result. Even after I had acquired a fair degree of manual dexterity in suturing the bowel, I seldom spent less than an hour in making a circular enterorrhaphy by a double row of sutures. In opening the abdomen for intestinal obstruction, usually a considerable length of time is spent in finding the obstruction, and when this is found and the patient manifests symptoms of collapse, a radical operation, which for its performance requires an hour or more, is often abandoned and the operation is finished by making an artificial anus, which at

the present time must be looked upon as a reproach upon good surgery. The last objection to the Czerny-Lembert method of suturing requires no argument. Any surgeon who hastily transfixes the bowel with a needle from 30 to 40 times in applying the Lembert suture is liable to perforate the whole thickness of its walls once or more; and if silk is used as suturing material, the puncture may become the seat of a perforation, and the direct cause of a fatal peritonitis. This is more particularly the case in operating on the bowel in cases of intestinal obstruction, as under such circumstances the walls of the bowel have become greatly attenuated from overdistention, and consequently more liable to become perforated by the needle. But the use of so many sutures, from 30 to 40 as recommended, brings with it another source of danger—gangrene of the inverted margin of the bowel. The second row of sutures applied in such close proximity must materially affect the blood supply to the inverted margin of the bowel, which in some instances must terminate in gangrene. Such a result is the more likely to ensue as the inner surface of the bowel is exposed to all dangers incident to infection from the intestinal canal,—in other words, an aseptic condition for one side of the wound cannot be secured, consequently the gangrene is of a septic character, which is prone to extend beyond the primary cause which produced it. To obviate some of these dangers I experimented with a modification of Jobert's invagination suture. According to Madelung the ingenious method of circular suturing devised by Jobert was practiced only in four cases, and two of the patients are known to have recovered. A number of years ago, I was forced to resort to resection of a part of the small intestine in a very complicated case of ovariectomy and resorted to this method, and although the patient died 48 hours after the operation from causes outside of this complication the bowel was found permeable and quite firmly united, and had the patient lived, I have no doubt the result of the resection and suturing would have been satisfactory. In Jobert's method the invagination sutures must be looked upon as a source of danger, as they were made to traverse the entire thickness of the wall of the bowel, and the material used was silk. It has been claimed that in this method the invaginated

portion of the bowel becomes gangrenous as in cases of invagination from pathological causes. This claim has arisen from a theoretical, and not from an experimental standpoint. In cases of invagination the intussusceptum carries with it the mesenteric vessels intact in the form of an arch which by constriction at the neck of the intussusciens is prone to become strangulated, an event which is followed by œdema and inflammatory swelling of the invaginated portion which rapidly tends to complete venous stasis and gangrene. In circular suturing by Jobert's method the intussusceptum has no vascular connection with the intussusciens. The vascular arch is interrupted and consequently the danger arising from venous obstruction is almost completely obviated. My experiments will show that gangrene of the invaginated portion as a rule does not occur. My modification of Jobert's method consists essentially in the use of a thin elastic rubber ring for lining the intussusceptum to prevent ectropium of the mucous membrane, to protect the mucous membrane of the bowel against injurious pressure from the suture, to keep the lumen of the bowel patent during the inflammatory stage, and to assist in maintaining coaptation of the serous surfaces, and finally the substitution of catgut for silk as invagination sutures. My method of proceeding is as follows: The upper end of the bowel which is to become the intussusceptum is lined with a soft pliable rubber ring made of a rubber band, transformed into a ring by fastening the ends together with two catgut sutures. This ring must be the length of the intussusceptum, from one-third to half of an inch, the lower margin is stitched by a continuous catgut suture to the lower end of the bowel which effectually prevents the bulging of the mucous membrane a condition which is always difficult to overcome in circular suturing. After the ring is fastened in its place the end of the bowel presents a tapering appearance which materially facilitates the process of invagination. Two well-prepared fine juniper catgut sutures are threaded each with two needles. The needles are passed from within outwards transfixing the upper portion of the rubber ring and the entire thickness of the wall of the bowel and always equidistant from each other; the first suture being passed in such a manner that each needle is brought out a short dis-

tance from the mesenteric attachment, and the second suture on the opposite convex side of the bowel. During this time an assistant keeps the opposite end of the bowel compressed to prevent contraction and bulging of the mucous membrane. The needles next are passed through the peritoneal, muscular and connective tissue coats at corresponding points about one-third of an inch from the margins of the opposite end of the bowel, and when all the needles have been passed an assistant makes equal traction on the four strings and the operator assists the invagination by turning in the margins of the lower end evenly with a director, and by gently pushing the rubber ring completely into the intussusciens. The invagination accurately made, the two catgut sutures are tied only with sufficient firmness to prevent disinvagination should violent peristalsis follow the operation. This is their only function. The invagination itself effects accurate, almost hermetical sealing of the visceral wound. The intestinal contents pass freely through the lumen of the rubber ring from above, downwards and escape from below is impossible as the free end of the intussusciens secures accurate valvular closure. After a few days the rubber ring becomes detached, and by giving way of the catgut sutures is again transformed into a flat band which readily passes off with the discharges through the bowels. The invagination sutures of catgut are gradually removed by substitution on part of the tissues, hence the punctures in the bowel remain closed either by the catgut or by the products of local tissue-proliferation; and thus extravasation is prevented. In my first experiments I used three invagination sutures, but found by experience that two are just as efficient in making and retaining the invagination. No superficial or peritoneal sutures were used in any of the cases, sole reliance being placed upon the invagination to maintain approximation and coaptation. The mesenteric attachment, both of the intussusceptum and intussusciens was separated only a few lines to enable invagination without too much narrowing of the lumen of the intussusciens.

Experiment 42.—Dog, weight 15 pounds. Three invagination sutures were used. The ileum was cut completely across at a point

about three feet above the ileo-cæcal region. Depth of invagination one inch. For two days after operation a slight rise in temperature; no symptoms of obstruction during the whole time. Animal in good condition when killed two weeks after operation. Omentum adherent at point of operation as well as on adjacent loop of intestine. Union between intussusceptum and intussusciens firm, no signs of gangrene. Narrowest portion of lumen of bowel was large enough to pass the little finger to second joint. An enterolith composed of fragments of wood, bone, etc., in the centre of which the straight rubber band which had been the rubber ring, was found just above the seat of operation. No distention of the bowel above this point. Bowel considerably flexed at seat of invagination, this condition being evidently brought about by inflammatory adhesions.

Experiment 43.—Dog, weight 20 pounds. Section of bowel and invagination with rubber ring the same as in the foregoing experiment. In subsequent history no mention is made of any symptom of obstruction, but for the last few weeks it was noticed that the dog began to emaciate. He died suddenly 81 days after the operation. Diarrhœa was a prominent symptom toward the last. No adhesions and no peritonitis. An enormous enterolith composed of all kinds of crude material, and again holding in its centre the rubber band, was found just above the invagination. Bowel at this place considerably dilated. Intussusceptum firmly adherent, a false passage admitting the tip of the little finger had been made on one side between it and the intussusciens. Death in this case was evidently produced by the enterolith. In this, as in the last case, the invagination was made at least an inch in length, and the collection of the crude, indigestible material, which the dog must have eaten in large quantities, around the detached rubber ring gave rise to the enterolith. The wall of the bowel surrounding the foreign body was not only dilated, but also greatly thickened. It is a well known fact that even a moderate degree of stenosis of the bowel in dogs is liable to give rise to the formation of an enterolith, as the crude material which these animals swallow becomes arrested and by constant accretions of the same kind of material, the enterolith forms and continues to increase in size until its presence causes catarrhal inflammation and finally intestinal obstruction.

It is quite possible that the lower end of the intussusceptum in the last case became impermeable during the inflammatory stage, and that the false passage was formed on this account by perforation on one side of the intussusceptum, an accident which was plainly traceable to too deep invagination.

Experiment 44.—Dog, weight 40 pounds. This experiment is interesting only from the fact that it shows that it is possible to make a mistake in the direction of the invagination, even after the operation has determined with accuracy which is the ascending and descending end of the gut, and to show the disastrous consequences which must necessarily follow such a technical mistake. The invagination was made in the usual manner with rubber ring and three catgut sutures. The animal appeared to be quite ill the day following the operation, and on the next day the thermometer showed a rise in temperature to 104.2°F. On the third day the dog died with well marked symptoms of perforative peritonitis. Recent peritonitis with some agglutinations of intestines. Considerable quantity of sero sanguinolent fluid in the peritoneal cavity. To my utter astonishment, I found that an ascending invagination had been made. Circular gangrene of intussusceptum and complete separation of ends was found. The rubber ring remained *in situ* still attached to the intussusciens by the catgut sutures, which had become somewhat softened. The invagination had decreased considerably by the traction caused by the peristalsis and by the pressure of the intestinal contents from above the obstruction, and the extensive gangrene of the bowel was undoubtedly determined to a great extent by these causes.

Experiment 45.—As an illustration of another source of danger due to faulty technique, I will relate this experiment. Medium-sized dog. Circular enterorrhaphy was done with the rubber ring two feet above the ileo-cæcal valve. In making the invagination it was noticed that the ring was too large, as it was seen that it caused too much pressure. Thinking that the parts might adapt themselves to this pressure, the bowel was replaced and the abdominal wound closed. The dog died 36 hours after the operation. Abdominal wound not united; omentum and intestines adherent to each other, and at point of operation. The circumscribed gangrene of the intussusciens was evidently entirely due to pressure on part of the rubber ring. The intussusciens was much swollen, a condition which materially aggravated the pressure caused by the rubber ring. With the following experiment two new departures were inaugurated, viz.: Instead of three invagination sutures only two were used, a change which still further shortened the time for performing the operation, and the use of Nothnagel's test in determining the direction in which the invagination should be done. In all of the remaining experiments of circular enterorrhaphy which were made only two catgut sutures were used. Until now it was always necessary to find one of the extremi-

ties of the small intestines for the purpose of determining which was the afferent and which was efferent end of the tube, so as to make the invagination in the right direction, a procedure which often required considerable time, and brought additional risk by increasing the shock of the operation and the danger of traumatic infection.

NOTHNAGEL'S TEST.

In experimenting upon animals for the purpose of studying the functions of the intestinal canal in health and disease, Nothnagel made the discovery that when the salts of potash are brought in contact with the serous surface of the bowel circular constriction takes place, and when the peritoneal surface is touched with a crystal of common salt ascending peristalsis is produced. The sodic chloride test I applied in 16 cases, and found Nothnagel's observations corroborated in 15 cases, by subsequent anatomical examination. In the remaining case where a wrong conclusion was drawn the error might have been due to a faulty observation, or the observation was not continued for a sufficient length of time. If, in the human subject these observations could be verified, it would be of great practical importance to surgeons in operations on the intestinal canal whenever it becomes necessary to determine which is the ascending or descending part of the bowel.

Experiment 45. Dog, weight 30 pounds. Circular section of ileum and immediate enterorrhaphy by invagination with rubber ring and two catgut sutures. Intussusceptum invaginated not more than a quarter of an inch. A few days after the operation stools mixed with blood, no other unfavorable symptoms. Animal killed fourteen days after operation. Wound united firmly. A number of omental and intestinal adhesions. A small abscess in mesentery at point of operation. No obstruction of any kind. On opening the bowel the walls at site of operation were very thick corresponding to the three intestinal coats, which had become considerably attenuated. The inner surface shows the point of junction of the intussusceptum with the intussusciptum in the shape of a circular ring of mucous membrane. The most contracted portion is large enough to admit the little finger.

Experiment 46. Dog, weight 15 pounds. Section of ileum and circular enterorrhaphy with rubber ring and two catgut sutures. Depth of invagination one-third of an inch. No unfavorable symptoms after operation. Animal killed after seven days. Wound completely united. Firm union of visceral wound; no gangrene of intussusceptum. Rubber ring retained *in situ* by catgut sutures, which are easily torn. Upper end of rubber ring matted with hair. No obstruction. Lumen of bowel somewhat contracted by a circular ridge of mucous membrane, which indicates the junction of the two invaginated ends of the bowel.

TRANSPLANTATION OF OMENTAL FLAP.

In most all post-mortem examinations of specimens from operations on the intestines, I observed that the omentum was adherent over a greater or less surface at the seat of suturing. I also observed that perforations never occurred wherever this additional protection to the peritoneal cavity had formed. To anticipate nature in protecting the peritoneal cavity in this manner I commenced to transplant an omental flap about an inch in width and sufficiently long to reach around the bowel, over the neck of the intussusciens, where it was fastened on the mesenteric side by two catgut sutures. The flap was taken either from the margin of the omentum or from its middle, care being taken to take some portions supplied with a vessel of considerable size. Its base was left attached to the omentum, all bleeding points were carefully tied with catgut ligatures. The two catgut stitches used for its fixation were passed twice through the flap, its base and free end, and the mesentery in such a way that when tied the direction of the suture corresponded to the course of the mesenteric vessel, so that after tying they would not interfere with the vascular supply of the bowel. When the flap was taken from middle of the omentum, the lateral halves were united with one or two catgut sutures before closing the abdominal wound.

Experiment 47. Dog, weight 40 pounds. Ileum divided 18 inches

above ileo-cæcal region, and the ends united by invagination with rubber ring and two catgut sutures. Transplantation of omental flap one inch in width around the whole circumference of the bowel over neck of intussusciens, fixation with two catgut sutures on mesenteric side. Invagination one-third of an inch in depth. Animal killed two weeks after operation. Abdominal wound perfectly healed. Omental flap firmly adherent to bowel over neck of intussusciens. Bowel at seat of operation much thickened; rubber ring gone; lumen of bowel at its most contracted point large enough for the passage of the little finger.

Experiment 48. Dog, weight 20 pounds. Complete division of ileum and immediate union of divided ends by invagination with rubber ring and two catgut sutures. Transplantation of omental flap two inches in width over the neck of the intussusciens. On third day stools mixed with blood. Died on the 5th day. Wound not united; omental flap firmly adherent except at a small point on mesenteric side where a minute perforation had taken place from circumscribed gangrene of the intussusceptum. Rubber ring only loosely held by one of the sutures. Lumen in invaginated portion quite narrow, but permeable.

Experiment 49. Dog, weight 15 pounds. Complete section of ileum and union of divided ends by invagination. The rubber ring used was only one-third of an inch wide, while formerly none were used less than half an inch in width. Neck of intussusciens protected by an omental flap two inches wide. The dog remained perfectly well, and was killed 25 days after operation. Abdominal wound completely healed, covered on the inner side by adherent omentum. Rubber ring gone. Lumen of bowel at most contracted point readily admits the little finger. No signs of obstruction. Omental flap adherent throughout.

Experiment 50. Dog, weight 22 pounds. Division of ileum and suturing in usual manner by invagination with rubber ring and two catgut sutures; transplantation of omental flap.

The dog remained perfectly well and was killed 23 days after operation. A number of intestinal adhesions produced several flexions. Point of operation four feet above the ileo-cæcal region. Omental flap firmly adherent to bowel throughout. Rubber ring gone. Lumen of bowel in invaginated portion quite large. The invaginated portion atrophic and retracted so that it appears in the shape of a firm ring and indicated in the interior by a circular prominence of the mucous membrane. No evidence of obstruction.

Experiment 51. Dog, weight 15 pounds. Complete division of the ileum and reunion of ends by invagination. Transplantation of omental flap two inches in width over neck of intussusciens, two cat-gut fixation sutures. Second day after operation stools bloody. After this time all functions normal. Animal killed forty-four days after operation. Point of operation four feet below the pylorus. The invaginated portion atrophied and retracted to such an extent that the bowel at this point only presents a thickened ring with its lumen only slightly narrowed by a circular ridge of mucous membrane. Omental flap firmly adherent all round and greatly atrophied.

REMARKS.—In circular enterorrhaphy, as in cases of intestinal wounds of any kind, the ideal of any operation should be to bring in continuous uninterrupted apposition a large surface of serous membrane, without, at the same time, interfering with the vascular supply of the parts which it is intended to bring together for permanent union by cicatrization. If in employing the Czerny-Lembert sutures more than a few lines of the margins of the bowel is inverted and included between the two rows of sutures, there is great danger of causing primary traumatic stenosis by the projecting circular ring in the lumen of the bowel. The narrowing of the lumen of the bowel must be as great, if not greater, than after invagination. That the second row of sutures has often been the cause of gangrene of the inverted margin of the bowel would not be difficult to prove by many post-mortem records and specimens. By invaginating to the depth of a quarter or third of an inch accurate coaptation is secured of the corresponding serous surfaces between the intussusceptum and intussusciens, which is made more secure and effective by the elastic pressure exerted by the rubber ring. This method of coaptation furnishes a large peritoneal surface of peritoneum for immediate union by cicatrization. With perhaps one exception, all of my experiments have shown that when cat-gut is used for invagination sutures none of the failures were attributable to their presence. On the inner side of the bowel the rubber ring is drawn against the puncture, and would thus furnish a mechanical protection against the escape of fluids

along these minute canals; besides the swelling of the catgut where it becomes softened by the fluids of the tissues would most effectually plug the punctures until a permanent plug is furnished by the granulations which in time completely remove the catgut by substitution and close the punctures permanently by a minute cicatrix. One great advantage of the rubber ring consists in its furnishing absolute protection to the bowel against pressure by the invagination sutures during the invagination, and subsequent traction from peristaltic contraction should the latter cause tension of the sutures, an occurrence which is not likely to arise if the invagination has been properly done. A circular enterorrhaphy as described above can be done in 15 minutes which certainly compares very favorably with any other procedure as far as time is concerned. In the description of a number of the specimens it has been distinctly stated that injurious results followed the stenosis caused by the invagination, and this might be urged as an argument against the safety and applicability of the operation. As compared with the human subject the dog is an unfavorable animal for circular enterorrhaphy by invagination. In the first place, the walls of the bowel are much thicker in proportion to its lumen than in man, a condition which necessarily seriously affects the lumen of the intussusceptum. Again the dogs were allowed to eat what they desired before and after the operation, and the quantity was not limited, consequently a great deal of indigestible substances, often of the coarsest kind, as straw, fragments of wood, or bone, hair, etc., found their way into the intestinal canal, and in a number of cases were arrested at the point of narrowing in the bowel, where they gave rise to the formation of an enterolith. In one instance death resulted clearly from intestinal obstruction from such a cause. In men the coats of the bowel being thinner and the lumen correspondingly larger, invagination is done with greater ease, and the danger from stenosis could hardly come into question as the fluid contents of the small intestines would pass readily through the rubber tube. Some of the older specimens prove that the traumatic stenosis caused by the invagination gradually diminishes by atrophy

of the invaginated portions which finally only appear as a prominent ridge of mucous membrane on the inner surface of the bowel, the remaining coats having completely or nearly disappeared by retrograde metamorphosis and absorption. In the healing of all wounds one important condition for an ideal result is rest. The rubber ring in the intussusceptum secures this important condition for the invaginated portion, as the elastic pressure must overcome peristaltic action and secure for this segment of the bowel, as near as possible absolute physiological rest. The danger of stenosis after invagination is greatest as soon as inflammatory swelling makes its appearance, a day or two after the operation, and the rubber ring is again in the right place to prevent any undue swelling by affording a gentle support for the invaginated portion, which cannot fail in preventing undue venous engorgement and œdema, which would otherwise follow the invagination. It serves both the purpose of a splint and an elastic bandage. After union of a bowel by invagination with a rubber ring peritoneal sutures are superfluous as the invagination itself most effectually prevents any escape of intestinal contents by the valvular action of the invaginated portion; at the same time the serous surfaces are kept in permanent and uninterrupted contact by the elastic pressure on part of the rubber ring.

Although the experiments have demonstrated the safety of the catgut invagination sutures in operating upon dogs, the same innocuity might not attend operations after intestinal resections for obstruction, as in such cases the coats of the bowel are almost without exception very much attenuated, and consequently the danger of extravasation along the needle punctures would be increased. Very recent trials have satisfied me that invagination after circular resection can be done with the rubber ring with facility and probably greater safety by dispensing with the invaginating sutures and adopting the following plan: The lower end of the intussusceptum is lined with a soft rubber ring about one quarter to one-third of an inch in width, and its lumen of sufficient size to afford free transit to the intestinal contents. The lower margin of

the ring is stitched to the end of the intussusceptum by a continued fine catgut suture. The ends of the bowel are now brought in contact and fastened together with four catgut sutures which are placed equidistant from each other. Invagination is now made by gently pushing the ends of the bowel in opposite directions being careful to push the ring sufficiently deep so that its upper margin is grasped by the neck of the intussusciens. A few superficial sutures are applied simply for the purpose of preventing disinvagination: the four catgut sutures act as invagination sutures, and at the same time prevent ectropium of the mucous membrane of the lower end of the bowel during and after invagination. With proper facilities and good assistance, a circular enterorrhaphy can be made in this manner without using invagination sutures in ten minutes, and by using not more than four retention sutures the blood supply to the inverted portions is not impaired, and at the same time the two ends of the bowel have been joined together by a large surface of peritoneum, which is held in accurate contact for rapid union by granulation and cicatrization. The advantages that are derived from covering a sutured intestinal wound by an omental flap are self-evident. The procedure is simply an imitation of nature's process in protecting the peritoneal cavity against perforation and in hastening the healing of the visceral wound. An adherent omentum secures rest for the part to which it has become attached. As the omental flap becomes firmly adherent before definitive healing of the visceral wound has taken place, it furnishes additional protection, and in the event of a small perforation it guards against perforative peritonitis by mechanically preventing the entrance of pus into the peritoneal cavity. Should pus reach the omental flap after it has become firmly adherent it is not very probable that perforation would take place through the two layers of peritoneum furnished by the adherent omental flap, and the subsequent healing of the perforation of the bowel would be most likely to take place. I shall again refer to this subject under the head of "Omental Grafting."

IV. INTESTINAL ANASTOMOSIS.

By an intestinal anastomosis we understand a condition of the intestinal canal where on account of an obstruction or complete occlusion, the intestinal contents are directed into a segment of the bowel below the seat of obstruction or occlusion through a fistulous opening between the bowel above and below the seat of partial or complete occlusion. The idea of establishing such a communication between the bowel above and below the seat of obstruction originated with Maisonneuve, who, without testing the new procedure first on animals, operated on two cases, but as the result in each case was fatal, he seems to have become discouraged and abandoned the operation, and never published the communication on this subject which he had in preparation. In the Surgical Society of Paris, his proposition met with violent opposition from his contemporaries, who argued that the excluded portion of the intestine would become the seat of fæcal accumulation, which, even if the operation were a success would subsequently destroy the life of the patient. The subject was revived in 1863 by Hacken, who under the directions of Adelman made some experiments on dogs. For a long time the operation was completely forgotten until E. Hahn, of Berlin, very recently alluded to it again in commenting on his two cases of excision of the colon where circular enterorrhaphy could not be performed, and where an artificial anus was established. Both patients recovered from the operation, but all attempts to close the preternatural opening proved futile. The results of my experiments have shown conclusively that the fear of accumulation of fæces in the excluded portion of the intestine, that is the intervening portion containing the seat of obstruction and extending on each side as far as the new opening by which the anastomosis has been established, is unfounded. If this objection can be laid aside, it becomes evident that the operation of establishing intestinal anastomosis has a great future, and will soon become an established procedure in the treatment of intestinal obstruction, and as a substitute for circular suturing in some forms of injuries of the intestines, which require excision. When I first made my experiments of establish-

ing intestinal anastomosis, I made the operation by making an incision an inch and a half to two inches in length through the convex surface of each bowel, and sutured the wounds together by Czerny-Lembert sutures the same as in making a circular enterorrhaphy. The results soon showed that the operation was attended by the same dangers as suturing after circular resection, that is, gangrene of the margins of the bowel and perforation. Dr. M. E. Connel, Superintendent of the Milwaukee County Hospital, suggested the use of perforated plates for making the lateral apposition in place of suturing. A few crude experiments were made with perforated discs of lead, wood, gutta serena, and leather, and the results soon satisfied us of the expediency and greater safety of uniting the intestines in this manner. Although the first experiments were very imperfect, and faulty in technique, almost every animal recovered. In the first experiments no needles were used. Around the oval perforation four catgut or silk sutures were tied; a slit was made in the bowel on the convex side parallel with its axis and large enough to permit the passage of a plate about an inch in width and about 2 1-2 inches in length. After making the incision and introducing the plate above and below the seat of obstruction the two wounds were brought into apposition, and the corresponding strings tied together with sufficient firmness to bring the flattened surfaces into accurate coaptation. The threads were cut short and the ends pushed inward out of sight. Experience showed that although the apposition was good, a tendency was observed on the part of the margins of the wound to evert on account of the bulging of the mucous membrane. I consequently modified the operation by arming the lateral threads with a needle with which the margin of the incision about the middle of the wound was transfixed. This proved a step in the right direction, as the lateral sutures completely prevented eversion of the margins of the wound, at the same time they fixed the plates in their position, and lastly at once transformed the longitudinal slit into an oval foramen of sufficient size for the free passage of intestinal contents. After many trials with different kinds of materials for the plates, I came to the conclusion that decalcified or partially decalcified

bone plates preserved after the decalcification in pure alcohol served the best purpose.

DIRECTIONS FOR PREPARING BONE-PLATES.

The compact layer of an ox's femur or tibia is cut with a fine saw into oval plates, one-fourth of an inch in thickness, two and one-half to three inches in length, and an inch in width. The plates are then decalcified in a ten per cent solution of hydrochloric acid, changed every twenty-four hours until they have become sufficiently soft that they can be bent in any direction without fracturing. After decalcification they are washed by letting water flow over them from three to six hours so as to remove the acid. The plates are then covered with porous paper and compressed between two pieces of tin until they are perfectly dry. If during the process of drying the plates are not compressed between two smooth surfaces they become distorted by warping. The hardened plates are next drilled several times in a straight line in the centre, and the openings enlarged and connected with a file, until the perforation is five-eighths inch in length and about one-eighth to one-sixth inch in width. The sharp margins of the plate and perforations are removed with a file. With a fine drill the four perforation for the sutures are made near the margin of the oblong perforation, one at each end and one at each side. For preservation the plates are kept in absolute alcohol. When the plates are to be used they are washed in a two per cent solution carbolic acid, and the threads or sutures attached by threading two fine sewing needles, each with a piece of aseptic silk, twenty-four inches in length, which are tied together. The threads are then fastened to the surface of the plate by another thread passing through the perforations in the shape of a loop and fastened at the back.

Instead of describing the experiments in their chronological order, I will enumerate them according to the part of the intestine operated upon, commencing with the lower portion of the intestinal tract.

I. GASTRO-ENTEROSTOMY.

As gastro-enterostomy is an operation which establishes an anastomosis between the stomach and the upper portion of the intestinal canal, with exclusion of the duodenum, and sometimes a portion of the jejunum, and is performed in cases of obstruction in the pylorus or duodenum, it comes within the legitimate sphere of this paper. Gastro-enterostomy, as heretofore described and performed, is an operation attended by many difficulties, and requires even in the hands of an expert an hour or more for its execution. As this operation is only done in cases greatly debilitated by disease and long suffering, anything which will simplify the technique and shorten the time must be looked upon as an improvement. An operation that can be done in ten minutes instead of an hour or two, and which even furnishes better conditions for the healing of the visceral wounds must take the place of the more complicated procedures which so far have only been practised in the hands of the most experienced surgeons.

Experiment 52. Dog, weight 25 lbs. Incision made through linea alba from xiphoid cartilage to near umbilicus. Omentum pushed to one side, and the stomach drawn forward into the wound; near the middle of its anterior surface a longitudinal incision was made, two inches in length, and a perforated gutta percha plate to which four medium-sized juniper cat gut sutures were attached, was introduced. The lateral sutures, armed with needles, were passed through the entire thickness of the walls of the stomach, half way between the angles of the wound. A similar incision was made into the intestine at the junction of the duodenum with the jejunum: the same kind of plate introduced and the margins of the wound punctured by the lateral armed sutures when the two wounds were brought *vis a vis* and the corresponding sutures tied. In tying the sutures the lower lateral suture is tied first, and the threads cut short; next the sutures corresponding to each angle of the wound are tied, and lastly the upper lateral. The serous surfaces of the stomach and intestine over an area corresponding to the size of the plates were brought into accurate permanent contact by the tying of the sutures. The stomach was replaced and the abdominal wound closed. The animal was allowed to eat immediately after the operation, and manifested no signs of illness

or pain, and was killed seven days after operation. Abdominal wound healed. Omentum adherent to its inner surface. Union between stomach and bowel firm over the entire surface of approximation. Plates detached, the one in the bowel had passed, while the other was found loose in the stomach. The new opening large enough to pass the index finger.

Experiment 53. Dog, weight 50 lbs. The operation was performed in the same manner as in the previous experiment, but great difficulty was experienced in bringing the stomach forward, as this organ was distended to its utmost with an enormous quantity of solid food. Evacuation was effected through the incision, aided by attempts of the animal to vomit, the violent contractions of the stomach forcing the food toward the opening, from where it was removed with fingers and spoon. After the stomach was emptied it was washed out with warm water. For the stomach a bone plate, only partially decalcified, was used, while the approximation plate in the bowel was fully decalcified. The four approximation sutures were of catgut. Several portions of omentum, which were soiled during the emptying of the stomach, were excised. The abdominal cavity was thoroughly irrigated with warm water before the wound was closed. The animal died the next day, and on opening the abdomen it was ascertained that the immediate cause of death was hemorrhage, as the peritoneal cavity was filled with blood. The bleeding undoubtedly took place from the omentum, by slipping or loosening of one of the catgut ligatures.

Experiment 54. Medium sized dog. Operation performed in the same manner with decalcified bone plates and catgut sutures. The first two days the animal had several attacks of vomiting, subsequently showed no signs of suffering. Appetite good and stools regular. Killed 34 days after operation. Omentum adherent to inner surface of abdominal wound. At point of operation stomach is contracted, so that the organ presents an hour-glass appearance. Interior of the organ contains a large mass of hay and fragments of bone. New opening large enough to pass index finger. Union between stomach and bowel over entire surface of approximation. Water passed into the stomach, flows through the pyloric orifice and the new opening in a stream of equal size.

Experiment 55. Large bull-dog. Approximation of anterior surface of stomach with bowel by perforated gutta percha plates, and four catgut sutures. Length of visceral incisions, two inches. The day after operation animal vomited his dinner, subsequently no unfavorable symptoms. Animal killed fourteen days after operation. Abdominal

wound well united. Omentum adherent to wound, duodenum, liver and at point of operation. Firm adhesions between stomach and bowel. Water passed into the stomach, only passed through the pyloric orifice. On opening the stomach, it was found that the wound in the stomach and intestine had completely healed, the site of incisions being marked by a narrow firm cicatrix. The failure of obtaining an anastomotic opening between the stomach and intestine could only be attributed to one of two causes, viz., either the perforations in the plates were too narrow, or the needles of the lateral sutures included too much tissue ; either cause would bring about approximation of the margin of the wounds and permanent closure of the opening by granulation and cicatrization.

REMARKS.—All of the animals recovered, except in case of experiment 53, without any untoward symptoms, although they were allowed to eat immediately after the operation, and the diet was not selected or restricted at any time. In the fatal case death was caused from complications which had no connection with the gastro-intestinal opening. In all of the specimens examined the mucous membrane of the stomach and intestine which had been interposed between the approximation plates presented a healthy appearance, showing that the pressure of the plates had exercised no injurious effect on this structure. More recent experience with this operation on animals has revealed the fact that in the stomach a completely decalcified bone plate is digested almost completely in thirty-six to forty-eight hours. It would, therefore, appear advisable to use only partially decalcified bone which remains for a longer time, so that in case of delayed union the approximation would be maintained for a sufficient length of time. As these animals subjected to the operation recovered promptly, and under the most unfavorable conditions, we have every reason to believe that this operation will be attended by the same favorable results when done for pyloric or duodenal stenosis in man, where a careful preparatory and after treatment cannot fail to facilitate the operation and to improve the conditions for the formation of early adhesions and a speedy definitive healing of the wound. I have no hesitation in recommending it as a substitute for the more time-consuming and less certain operation by the tedious and difficult method of double suturing which is now generally practised.

2. JEJUNO-ILEOSTOMY.

In this operation some form of intestinal obstruction, either complete by division of the bowel and closure of both ends, or partial, by making a volvulus, invagination or flexion in the vicinity of the juncture of the jejunum with the ileum, and intestinal anastomosis made by establishing a communication between the bowel above and below the obstruction. Before I made use of the perforated approximation discs this was accomplished by making an incision an inch and a half or two inches in length through the convex surface of the bowel above and below the obstruction and uniting the wounds by a double row of sutures. An operation of this kind usually lasted over an hour, while the rapid operation of coaptation by perforated discs seldom took more than fifteen minutes.

(a) JEJUNO-ILEOSTOMY BY SUTURING.

Experiment 56. Large cat. Invagination of ileum into ileum in a downward direction, and fixation of intussusceptum to neck of intussusciens by two fine catgut sutures to prevent spontaneous reduction. Intestinal anastomosis by establishing an opening an inch in length, suturing by Czerny-Lembert method. The animal never recovered from the shock of the operation, and died in less than twenty-four hours. Length of intussusceptum two inches, which, after the removal of the sutures, could not be reached by traction, as the bowel was firmly constricted by the neck of the intussusciens, and recent adhesions had formed. No peritonitis: suturing found perfect.

Experiment 57. Dog, weight 65 lbs. Intestinal obstruction by making acute flexions in upper portion of ileum, fixation of loops of intestine by fine catgut sutures. Intestinal anastomosis between jejunum and ileum by incision and double suturing. The animal died on third day with symptoms of perforative peritonitis. On close examination, one of the superficial approximation sutures had been passed through the whole thickness of the wall of the bowel, and it was here that perforation had taken place. Recent diffuse general peritonitis.

Experiment 58. Dog, weight 17 lbs. Descending invagination of ileum into ileum, length of intussusceptum three inches, fixation by two catgut sutures. Formation of intestinal anastomosis between the bowel above and below the invagination by incision and double suturing. Animal died on third day with symptoms of perforative peritonitis. Abdominal wound not united. Adhesions at point of operation quite firm. Diffuse general peritonitis from a perforation which had

been made by a sharp fragment of bone above the new opening. Intussusceptum not gangrenous.

Experiment 59. Dog, weight, 23 lbs. Intestinal obstruction was made by producing a volvulus in the upper part of the ileum. Restoration of continuity of intestinal canal by making a jejuno-ileostomy by lateral apposition and double suturing. Day after operation intestinal discharges were bloody; after this time normal. Animal in perfect health when killed sixty-seven days after operation. The volvulus was found in same condition as after operation; the intestinal loop empty, atrophied and adherent to adjacent loops of intestine. Bowel above seat of obstruction and as far as the new opening empty. Intestinal tract above and below the obstruction presents no indication of the presence of an obstruction. New opening oval in shape and as large as the lumen of the bowel at that point.

Experiment 60. Large maltese cat. Intestinal obstruction by making two flexions in ileum, about eighteen inches apart, after this portion had been cleared of its contents. Flexions made by doubling the bowel toward its convex side, and fixing it in this position by fine catgut sutures. Jejuno-ileostomy by lateral apposition and suturing. Vomiting day after operation; stools scanty the first few days, and later complete obstruction. Died nineteen days after operation. Wound completely united; no general peritonitis; flexions remained; bowel between them contained a slight amount of fæcal matter. Bowel some distance above the new opening very much dilated, pointing to obstruction above new opening. On tracing the intestinal canal from above downward, this obstruction is seen to consist in acute flexion of the bowel by firm and extensive adhesions. New opening sufficiently large to admit the tip of the index finger, around the margins of which most of the deep sutures remain attached.

Experiment 61. Large cat. Obstruction made by two flexions in the ileum, the apices of which were united by catgut sutures. Intestinal anastomosis made by a jejuno-ileostomy. For eleven days the animal remained in good condition, when symptoms of perforative peritonitis manifested themselves, and death ensued two days later. External portion of wound not united. Numerous omental and intestinal adhesions. Flexions retained and their apexes adherent to each other by firm band of adhesion. Excluded portions above and below the obstruction empty. Two small perforations at point of suturing on anterior surface of bowel; remaining portion of wound firmly united. New opening sufficiently large to admit tip of index finger. Death from perforative peritonitis.

Experiment 62. Large, Newfoundland dog. Descending invagina-

tion of ileum into ileum to the extent of six inches; fixation of intussusceptum by two catgut sutures. Permeability of intestinal canal restored by making a jejuno-ileostomy; wounds united by a double row of sutures. Intestinal discharges normal throughout. No rise in temperature. General condition as good as before operation, when killed on the twentieth day. Abdominal wound completely united; no peritonitis; omentum adherent at site of operation. Invagination had reduced itself, and its location was marked by an acute flexion caused by extensive adhesions. No accumulation of intestinal contents in excluded portions. The new opening, at least two inches in length, a few of the deep sutures remaining attached to its margins. This opening was partially obstructed by a mass of hair and fragments of bone. On passing a stream of water from above downward, the fluid passed through an opening in the centre of this mass into the lower portion of the ileum, but not through the portion that was invaginated. After this mass was removed, the fluid was found to pass through the portion that was invaginated, as well as through the new opening.

The many failures which attended jejuno-ileostomy and ileo-ileostomy by lateral apposition and suturing led to the use of perforated approximation discs. A great contrast was observed in the animals operated upon by these two methods. The operation by suturing required usually more than an hour, and almost all of the animals showed more or less symptoms of shock after its completion, and not a few succumbed to its immediate effects: while the operation by approximation plates could always be finished within twenty minutes, consequently, the animals never suffered seriously from the immediate effects of the operation. The first experiments were made somewhat carelessly and with crude material, and yet it was observed that the healing process progressed more favorably and was accomplished in a shorter time than after suturing. The approximation discs brought into uninterrupted contact, large serous surfaces without impairing the vascular supply, at the same time they secured for the parts destined to become united an essential condition for rapid wound healing—rest—by serving the useful purpose of splints.

Experiment 63.—Dog, weight 15 pounds. Ileum was completely divided at its junction with the jejunum and both ends of the bowel closed by invagination, and three stitches of the continued suture.

An incision was made on convex side of bowel about two inches from the closed ends, and a heavy perforated lead plate to which six catgut sutures were fastened around the oval perforation was introduced into the lumen of the bowel of each closed end, all of the catgut sutures being brought out through the incision. The two wounds were brought opposite each other and the six sutures tied. The serous surfaces of the two intestines over a surface corresponding to the size of the lead discs were thus brought into accurate apposition. The sutures were cut short and the ends buried as deeply as possible. The condition of the animal remained excellent until the time of killing, 75 days after operation. Omentum adherent to wound; large intestines distended with normal fæces. Bowel above and below point of operation normal in size and structure. New opening between ileum and jejunum large enough to admit the little finger to second point. Bowels firmly united by a broad surface. Above the communicating opening a double flexion of the bowel was found which apparently had done no harm.

Experiment 64.—Dog, weight 18 pounds. Operation done in the same manner as in the last experiment, only that instead of lead the discs were made of sole leather, and the sutures used were linen in place of catgut. For a few days the temperature was higher than normal and appetite diminished. After fourth day the animal appeared to be in excellent condition and remained so for three weeks, when the appetite failed and occasional attacks of vomiting set in. These symptoms remained more or less prominent until the time of killing, 39 days after operation. Omentum adherent to abdominal wound; extensive intestinal adhesions at site of operation; union between intestines perfect. On incising the bowel it was found that the plates had sloughed through and had passed along the distal portion of the bowel, leaving an opening the size of the plates, the margins of which had almost completely cicatrized. The two leather plates still held together by the linen sutures were found three feet lower down in the ileum where they had become embedded in a mass of hair, straw and fæcal matter, and quite firmly impacted, causing complete obstruction of the bowel. The intestine above the seat of obstruction was enormously dilated, while below the seat of impaction it was empty and contracted. Large intestines likewise empty and contracted. The cause of the illness was evidently due to intestinal obstruction produced by the impaction of the large enterolith in the centre of which the leather discs were found.

Experiment 65.—Dog, weight 10 pounds. In this instance the bowel was divided near the junction of the jejunum with the ileum,

both ends closed and its continuity established by incising the convex surface of both ends and approximating the wounds by two perforated bone plates tied together by silk ligatures. The animal died 14 days after operation. During the last few days symptoms of intestinal obstruction were present. Abdominal wound completely united. Numerous intestinal adhesions at site of operation. Bone plates still *in situ* and firmly fixed. On proximal side perforation of bone plates completely closed by hair and fragments of bone, giving rise to complete intestinal obstruction. The bowel above this point was greatly dilated, while on distal side it was empty and contracted. Adhesions between the two intestinal surfaces included by the bone plates firm. Intestinal obstruction by a mechanical arrest of portion of the intestinal contents above the proximal plate had caused death before a more efficient communication could be established by sloughing through of the bone plates.

Experiment 66.—Dog, weight 30 pounds. Ileo-ileostomy by dividing the ileum near its centre, closing both sides, and after incising both ends on convex surface, brought wounds in apposition by perforated plates of cross-grained walnut wood, which were tied together with silk sutures. The dog remained in perfect health and was killed 18 days after operation. External wound completely united. Plates had become detached, leaving a communicating opening 2 inches in length. Blind ends of bowel empty; no trace of plates could be found.

Experiment 67.—Dog, weight 24 pounds. Double ileo-ileostomy. Ileum divided transversely five inches above ileo-cæcal region and both ends closed by invagination, and three stitches of the continued suture. Lower and upper end of bowel were again brought into communication by incision on convex side and lateral apposition of wounds by means of perforated approximation plates of decalcified bone, hardened in alcohol. The plates were fastened together by four silk sutures, all of the threads being brought out of the incision, tied and cut short. Above this point a loop of the ileum was made by bringing the convex surfaces into apposition after incision at two points, and introducing perforated gutta percha plates which were retained in place by four silk sutures. No fever or symptoms of obstruction followed the operation. Animal killed 13 days later. External wound firmly united. No evidences of peritonitis or intestinal obstruction. First operation left a communicating opening large enough to admit the little finger in one of its margins. The silk ligatures which had become detached from the plates had embedded themselves. The

decalcified bone plates had disappeared and no trace of them could be found in any portion of the intestinal canal lower down. The second operation was 30 inches higher up. Gutta percha plates remain *in situ*, although somewhat loosened by the gradual disappearance of the intervening tissues by pressure atrophy. Adhesions between the two surfaces of the bowel firm and extending a little beyond the line of approximation. The perforation in the proximal plate almost completely closed by an accumulation of hair. The entire ileum normal in size and appearance.

Experiment 68.—Dog, weight 54 pounds. Transverse section of ileum 30 inches above ileo-cæcal region and closure of both ends in the usual manner. The two closed ends were overlapped 4 inches and brought into communication by two longitudinal openings which were approximated by being buttoned together with a shuttle-shaped button, nearly $1\frac{1}{2}$ inches in length, the sides being lead plates and the shaft a rubber tube through which the anastomosis was established at once. As the margins of the intestinal wounds showed a tendency to evert, a fine catgut suture was inserted on each side embracing only the peritoneal coat. Only for two or three days after the operation did the dog not appear to be well. Killed 23 days after operation. Omentum adherent to abdominal wound which was firmly united. Omental adhesions to intestine at site of operation. Intestinal anastomosis 30 inches above the ileo-cæcal valve. Proximal blind end of bowel five inches in length adherent to distal end, considerably dilated and contains fragments of bone and other crude substances. Approximation button *in situ* and quite firmly fixed. A fragment of bone partly fills the lumen of the rubber tube. Coaptated peritoneal surfaces firmly adherent. The obstruction of the communicating tube had given rise to dilatation of the bowel above the point to twice its natural size, while below the seat of partial obstruction the intestine appeared empty and contracted.

Experiment 69.—Small dog. In this experiment the ileo-ileotomy was made by lateral apposition by perforated approximation plates of partially decalcified bone tied together by four catgut sutures. The lateral sutures were passed through the margins of the wound near its border, a modification of the usual procedure, which not only fixed the plates firmly in their places, but also prevented ectropium of the mucous membrane, and ensured free patency of the new opening by retracting the margins of the wound, so that the longitudinal slit is at once transformed into an oval shape. The animal showed no unfavorable symptoms and was killed 29 days after operation. Dog well

nourished. External wound united. Omentum adherent to wound and intestines. The proximal blind end of bowel contained one of the bone plates which showed signs of softening and disintegration. The bone plate in the distal end had been passed with fæces previously. The new opening perfect and sufficiently large to equal in size the lumen of the bowel.

Experiment 70.—Dog, weight 12 pounds. Made ileo-ileostomy the same as in the last experiment, using decalcified, perforated bone plates, which were tied together with four catgut sutures, the lateral ones being passed through the margins of the wound. An omental flap was used to cover the sides of the bowel where approximation had been made. This flap was retained by two fine catgut sutures. No unfavorable symptoms. Animal killed 23 days after operation. Omentum adherent to distal blind end. Omental flap in position and firmly adherent. Site of operation 14 inches above ileo-cæcal region. Both bone plates had disappeared and no trace of them could be found. Some hair had collected in the blind proximal end. New opening large enough to admit the index finger.

REMARKS.—Jejuno-ileostomy and ileo-ileostomy by internal apposition with decalcified perforated bone plates in cases of complete obstruction of the bowel artificially produced is an operation almost devoid of danger. Partially or completely decalcified bone plates hardened in alcohol remain firm for a sufficient length of time to answer the purpose of retentive measures until firm adhesions have formed between the serous surfaces held by them in approximation. Until it was ascertained by experiment that the plates would undergo softening and disintegration in the course of a few days, catgut sutures were used to hold them in place with the expectation that the plates would become detached and escape with the intestinal contents as soon as the sutures would give way. Experience, however, has shown that aseptic silk threads are preferable to catgut, as they can be tied with greater accuracy and the knots will never become loosened, while the approximation discs disappear completely by softening and disintegration in a few days. Approximation plates of inabsorbable material as lead, wood, leather, bone, and gutta percha, fastened together by silk or linen sutures remain *in situ* until the interposed tissues disappear by pressure atrophy, and the opening that results

corresponds in size to the dimensions of the plates. In the first experiments the plates were tied together by six sutures, but it was found that four sutures answered the same purpose. As a rule, the plates were about $2\frac{1}{2}$ inches in length, and their width corresponded to one-third of the circumference of the bowel. The greatest advantage to be found in the method of restoring the continuity of the intestinal canal by lateral apposition by approximation discs consists in the fact that the point of contact is always made on the convex surface of the intestines, so that the means resorted to to secure coaptation do not interfere with the blood supply from the mesenteric vessels. As this method requires much less time than any form of circular enterorrhaphy, and has been followed almost without exception by recovery, it recommends itself strongly as a substitute for the latter procedure in many cases where loss of time constitutes an important factor in the issue of the case, or where from other causes circular suturing appears impossible or impracticable.

3. ILEO-COLOSTOMY.

As the ileo-cæcal region is frequently the seat of intestinal obstruction it becomes desirable to devise some definite plan of operative treatment in cases where the cause of obstruction is not amenable to removal with a view of establishing the continuity of the intestinal canal, thus avoiding the necessity of resorting to the formation of an artificial anus. To accomplish this object two distinct methods were followed: (1) Division of the ileum with closure of distal and implantation of proximal end into colon. (2) Division of ileum, closure of both ends and lateral apposition of proximal end with colon, and the formation of an intestinal anastomosis by suturing or approximation discs.

(a) ILEO-COLOSTOMY BY IMPLANTATION.

Experiment 71.—Dog, weight 38 pounds. Intestinal anastomosis by implantation of the ileum into colon. The ileum was divided transversely just above the ileo-cæcal region, and the distal end closed by invagination and 3 stitches of the continued suture, and dropped

back into the abdominal cavity. A longitudinal incision in size corresponding to the lumen of the ileum was made in the ascending colon at a point directly opposite the mesenteric attachment, and the proximal end of the ileum was then fixed in this opening by Czerny-Lembert sutures. Only slight febrile reaction followed the operation. The appetite remained good and the discharges from the bowels were normal. The animal was in excellent condition when killed, 33 days after operation. Few circumscribed omental adhesions to abdominal wound, which was completely closed. Peripheral portion of ileum presents a conical appearance, and was found adherent to, and of the same length as the appendix vermiformis. Implantation had been done about the middle of the colon. Union at point of suturing perfect, apparently no interruption of continuity of peritoneal surface. The new opening into colon a little smaller than the lumen of the ileum. Around the margins of this opening, which somewhat resembles the ileo-cæcal valve, six of the deep silk sutures remain attached. Above the new opening the colon and cæcum were found empty and somewhat atrophic. Lower portion of the ileum and colon below the new opening appear normal in size and structure.

In the remaining experiments the implantation was made by lining the proximal end of the ileum with a narrow flexible rubber ring, which was retained in place by a continued catgut suture, embracing the free margin of the bowel and the lower margin of the rubber ring. The implantation was made by two catgut sutures threaded each by two needles and passed at opposite points from within outwards through the upper margin of the ring and the entire thickness of the bowel, while the needles were only passed through the serous and muscular coat of the colon. After both sutures were in place gentle traction upon all of the ends brought the end of the ileum into the incision in the colon, and the walls of the colon were drawn over the end of the ileum to the points where the needles emerged from the ileum, making really a limited invagination. When in proper position, the serous surfaces of the colon and ileum over a surface corresponding to the width of the rubber ring were in accurate coaptation, after the two sutures were tied. Only in exceptional cases was it found necessary to apply one or two additional superficial coaptation sutures. As in circular enterorrhaphy, so in these cases, the elastic pressure on part of the rubber ring rendered material assistance in maintaining accurate coaptation, while at the same time it secured rest for the sutured parts, and kept the new opening freely patent for the escape of intestinal contents into the colon.

This operation did not require one fourth of the time consumed in making an implantation by Czerny-Lembert sutures.

Experiment 72—Dog, weight 50 pounds. Division of ileum eight inches above ileo-cæcal region, distal end closed by invagination, and three stitches of the continued suture. Proximal end lined with rubber ring and implanted into incision of ascending colon by two catgut invagination sutures. The dog did not appear to do well after the operation, and died on the 5th day. Abdominal wound not united. Partial separation of implanted bowel and diffuse septic peritonitis from perforation.

Experiment 73.—Dog, weight 35 pounds. Ileum divided 12 inches above ileo-cæcal region, distal end closed and proximal end lined with flexible rubber ring and implanted into an incision in the transverse colon and retained by two invagination sutures of catgut. An omental flap an inch and a half in width was placed over the junction of the two intestines and fixed in its place by two catgut sutures. No unfavorable symptoms after operation. Animal when killed, 18 days later, in excellent condition. Omentum adherent to abdominal wound which was firmly united. Omental flap adherent all round. Colon above new opening ten inches in length, completely empty, contracted and atrophic. New opening oval in outline and as large as the lumen of the ileum.

Experiment 74.—Dog, weight 16 pounds. Division of ileum, closure of distal end and implantation of proximal into an incision of the colon by rubber ring and two invagination sutures of catgut. As the inverted portions of the colon showed a tendency to evert, two additional retaining sutures of fine catgut were used which secured perfect coaptation throughout. An omental flap was laid over the junction of the intestines and fixed in its place by one catgut suture. The dog remained in good condition, appetite unimpaired, and discharges from bowels normal. Killed 13 days after operation. Abdominal wound firmly united. Omentum adherent to wound. A number of adhesions between coils of intestine. Ileum somewhat dilated above the new opening. Omental flap in place and adherent. Union between ileum and colon perfect. A long, sharp fragment of bone was found lodged just above the new opening, its lower end partially occluding its lumen. The dilatation of the lower portion of the ileum was evidently due to partial obstruction from the presence of the foreign body in the new opening.

Experiment 75.—Dog, medium size. Section of ileum two feet above the ileo-cæcal region, closure of distal end in the usual manner,

implantation of proximal end into colon by rubber ring and two invagination sutures of catgut. No omental flap. Animal remained well and was killed 43 days after operation. Omentum adherent to abdominal wound. Distal end of ileum conical in shape, the extremity presenting a cup-shaped depression, which was filled with cicatricial material. Omentum adherent at ileo-cæcal region and at site of operation. Union between the bowels perfect and their serous surfaces appear to be continuous over the line of junction. The new opening from the colon admits the little finger, and is surrounded by a prominent ridge of mucous membranes, which resembled the ileo-cæcal valve.

Experiment 76.—Dog, weight 14 pounds. Division of ileum a few inches above ileo-cæcal valve, distal end closed by invagination, and 3 stitches of continued suture. Implantation of proximal end into colon by rubber ring and two catgut invagination sutures. Over the junction of the two intestines an omental flap was placed which was retained by a catgut suture. The animal showed no unfavorable symptoms and was killed 23 days after operation. Omental flap retained and firmly adherent throughout. Point of implantation three inches above cæcum; union between the two intestines firm throughout. New opening corresponds in size to the lumen of the ileum, and is surrounded by a prominent ridge of mucous membrane which appears to be derived from the invaginated portion of the ileum.

Experiment 77.—Ileum divided a few inches above ileo-cæcal region, and after closure of distal, the proximal end was implanted into the colon in the usual manner by means of rubber ring and two invagination sutures of catgut. Animal died on the third day after operation. Wound partially united; a considerable quantity of sero-sanguinolent fluid in the abdominal cavity. Ileum almost completely separated from colon, and the portion which had been invaginated showed signs of gangrene. Rubber ring had disappeared; death from perforative peritonitis. In this case we have reason to believe that the rubber ring which was used was too large and that the gangrene and separation was due to injurious pressure.

(b) ILEO-COLOSTOMY BY LATERAL APPPOSITION.

Anastomosis by this method was made after producing an intestinal obstruction of some kind at or near the ileo-cæcal region, and then by bringing the ileum above the seat of obstruction in communication with the colon below the point of

obstruction by making an incision an inch and a half to two inches in length in both intestines at a point opposite the mesenteric attachments, and uniting the wounds either by a double row of sutures or perforated decalcified bone discs. The first experiments were all made by suturing, but as in a circular enterorrhaphy it was found by experience that perforation not infrequently occurred along the track of one of the sutures, in some instances several days after the operation, at a time when union had taken place by firm adhesions. These unfavorable results led to the use of the approximation discs.

Experiment 78.—Dog, weight 25 pounds. The ileum was withdrawn from the abdomen through an incision in the linea alba and having emptied a loop of its contents acute flexion was made just above the ileo-cæcal region by approximating the serous surfaces of the convex side for an inch and a half by five catgut sutures. Two longitudinal incisions of equal size were made, one in the ileum six inches above the flexion, and the other in the ascending colon three inches above the cæcum. The visceral wounds were carefully united by Czerny-Lembert sutures, using silk for the deep interrupted sutures, and fine catgut for the superficial continued sutures. No untoward symptoms were observed after the operation; appetite remained unimpaired, and fæcal discharges were normal. The dog was killed 37 days after operation. Animal well nourished. No evidences of peritonitis. Bowel above point of obstruction nearly empty, and somewhat contracted as far as the new opening. Flexion permeable to a stream of water. Slight omental adhesions to bowel at site of operation; union firm throughout. Lumina of non-excluded portion of bowel normal in size above and below the flexion. Serous surfaces at point of junction appear perfect and continuous. On slitting open the colon opposite the new opening its outlines were seen to be marked by a prominent ridge of mucous membrane to which a number of the deep sutures remained attached. The opening was large enough to admit the tip of the middle finger. The excluded portion of the colon and the cæcum were somewhat contracted and atrophic and contained only a very small quantity of fæcal matter.

Experiment 79.—Medium-sized cat. About two inches of the ileum were invaginated into the colon through the ileo-cæcal valve, and the intussusceptum stitched to the neck of the intussusciens by two fine catgut sutures. Continuity of the intestinal canal restored

by incising the ileum above the obstruction and the ascending colon below the free extremity of the intussusceptum and uniting the wounds by a double row of sutures. The invagination caused no serious disturbance, and the animal remained in good health and was in excellent condition at the time of killing, 162 days after operation. A number of adhesions between the folds of the intestines near the site of operation. At point of junction of the two intestines the peritoneal surface presented a glistening and continuous surface. New opening an inch and a half in length, oval in outline and located five inches above the ileo-cæcal region. Two inches below the opening the invagination remains in the shape of a circular thickening of the bowel with a narrowing of its lumen to more than one-half of its normal size. A close inspection of the specimen shows that no gangrene has occurred, but that the intussusceptum has undergone atrophy. A stream of water passing along the ileum in a downward direction escapes through the invaginated portion and through the new opening, the stream from the latter being at least three times larger than the one through the intussusceptum. Excluded portion of ileum and colon empty and very much atrophied and contracted. Below the new opening the colon and rectum contain normal fæces in considerable quantity.

Experiment 80.—Young cat. Ileo-cæcal invagination; length of intussusceptum four inches, and in order to prevent spontaneous disinvagination the bowel was fixed in its position by two fine catgut sutures. Ileo-colostomy below the lower end of the intussusceptum by lateral apposition and suturing. Animal died on the fourth day after operation. Abdominal wound united. Diffuse peritonitis from perforation at site of suturing. Length of intussusceptum reduced from four inches to two inches and a half. It was found impossible to effect reduction by traction on account of firm adhesions at neck of intussusciens. No gangrene.

Experiment 81.—Adult, large dog. Intestinal obstruction was produced by making two sharp flexions near the ileo-cæcal region by folding the bowel on its side and fixing it in this position by fine catgut sutures; the apices of the flexions were sutured together so as to render the obstruction more complete. Intestinal anastomosis was established by lateral apposition and suturing. Physical condition of dog remained good throughout; appetite and evacuations normal. Killed 31 days after operation. No peritonitis; a number of omental adhesions at point of operation. Flexions quite sharp, rendering the bowel nearly, if not completely, impermeable at this point. Perfect

union between bowels, with some thickening of their walls by inflammatory exudation. New opening oval in shape, an inch and a half in length, a few of the deep sutures still remaining attached to its margins. Excluded portion of bowel empty and somewhat atrophic.

Experiment 82.—Dog, weight 13 pounds. Obstruction of the bowels made by an acute flexion four inches above the ileo-cæcal region, retained by four catgut sutures. Intestinal anastomosis by an opening an inch and a half in length which brings into communication the ileum above the obstruction and the descending colon. The animal showed no untoward symptoms, and was killed 41 days after operation. A number of intestinal folds agglutinated by adhesions; no evidences of diffuse peritonitis. Where the flexion had been made the loop of intestine is connected by a broad band of adhesion which gives to the bowel a horse-shoe shaped appearance. Intestine below the seat of flexion contains a small amount of hardened fæces. Colon and cæcum above the new opening nearly empty and greatly contracted. Line of suturing somewhat thickened. New opening oval in outline and about an inch in length, surrounded by a corrugated elevation of mucous membrane. A stream of water passed through the bowel from above downward readily escapes through the new opening, while only a small stream can be forced through the flexion.

Experiment 83.—Dog, weight 27 pounds. A volvulus was made six inches above the ileo-cæcal region by rotating an empty loop of the intestine once around its axis and fixing it in this position by three catgut sutures. Intestinal anastomosis between the ileum above the volvulus and the descending colon by lateral apposition and suturing. For four days after the operation the evacuations from the bowels contained blood; after this time the stools were normal. Dog in excellent condition when killed, 31 days after operation. No signs of diffuse peritonitis. The portion of bowel which constitutes the volvulus adherent, contracted and empty. Water can be readily forced through this part of the bowel. Cæcum and colon above new opening empty and contracted. Size of new opening larger than the lumen of the ileum, its margins surrounded by a prominent ridge of mucous membrane to which a few of the deep sutures still remain attached. In this experiment nearly the entire colon was excluded, consequently the fæcal discharges were quite frequent and fluid or semi-fluid in consistence.

Experiment 84.—Dog, weight 17 pounds. Two inches of the ileum were invaginated into the cæcum. Ileo-colostomy by uniting the ileum with the transverse colon by suturing. The animal appeared quite ill after the operation and died on the fifth day after having manifested

well marked symptoms of perforative peritonitis. Abdominal wound not united. Only partial union between the intestines at point of junction. Diffuse septic peritonitis from perforation.

REMARKS.—In at least two experiments which are not here reported the animals died a few hours after operation of shock. In a number of other experiments the operation was followed by more or less shock, but the animals, without receiving any special treatment, rallied after 6 to 12 hours. The symptoms referable to the immediate effects of the operation were due to the length of time required in applying a double row of sutures in uniting the visceral wounds, a step in the operation which always required from 30 minutes to an hour. These experiments only corroborate the statement previously made that the excluded portion of the intestinal canal, including the obstruction, does not become the seat of faecal accumulation, but undergoes atrophy after free intestinal anastomosis has been established between the intestine above and below the seat of obstruction. Experiments Nos. 68 and 69 furnish most striking proof that the danger of gangrene in cases of invagination is greatly diminished by establishing an early intestinal anastomosis, as when this is done the violent peristalsis is promptly arrested by furnishing a new outlet to the intestinal contents; at the same time the serious consequences resulting from pressure and distention above the obstruction are likewise promptly averted. In cases of intestinal anastomosis where nearly the entire colon has been excluded, the fluid contents of the small intestines reach the rectum at once, and cause frequent fluid faecal discharges, an occurrence which does not appear to impair the general health of the animal. The new opening should be made of adequate size so that its lumen will at least correspond to the lumen of the bowel above the obstruction.

(c) ILEO-COLOSTOMY BY PERFORATED APPROXIMATION DISCS.

Experiment 85.—Dog, weight 20 pounds. The ileum was completely divided three inches above the ileo caecal region, both ends closed by invagination and three stitches of the continued suture.

A communication was established between the proximal extremity and the colon, by making an incision into the ileum on convex side near the close end and introducing through this opening a perforated decalcified bone plate. A similar opening was made into the ascending colon opposite its mesenteric attachment through which a perforated plate of wood was introduced. To each plate were tied four catgut sutures. The lateral sutures were passed through the margins of the wound. After the plates and sutures were in place the wounds were brought in contact and the four sutures tied, which coaptated the serous surfaces of both bowels over an area corresponding to the size of the plates. The animal remained apparently well for two days, when symptoms of peritonitis set in and death occurred five days after operation. Diffuse peritonitis. Union at point of operation incomplete which resulted in a perforation. Discs had disappeared. As the catgut sutures were quite fine it is more than probable that partial separation of the plates occurred before adhesions had taken place between the serous surfaces of the coaptated bowels, which resulted in perforation and death from diffuse septic peritonitis.

Experiment 86.—Dog, weight 15 pounds. Invagination of colon into colon to the extent of two inches. Intestinal anastomosis by making an ileo-colostomy by lateral apposition of the ileum to colon below invagination, using perforated hard rubber plates which were tied together by four catgut sutures, the lateral sutures being passed through the margins of the wound. After tying the sutures it was found that at one point the margins of the wound showed a tendency to evert, consequently a fine catgut suture was passed through the peritoneum only and tied. The animal did not appear bright the day after the operation, but subsequently showed no signs of suffering; killed 24 days after operation. Abdominal wound firmly united. Omentum adherent to wound and at point of operation. The invagination was partially reduced. The bowel at this point was curved in the shape of a horse-shoe, but permeable to a stream of water. Excluded portion of colon tortuous and atrophic. Cæcum contained a small quantity of fluid fæces. Plates could not be found. New opening sufficiently large for free passage of intestinal contents.

Experiment 87.—Dog, weight 15 pounds. Ileum divided transversely 15 inches above the ileo-cæcal region; both ends closed in the usual manner. Ileum and colon approximated by decalcified perforated bone plates which were tied together by four catgut sutures, the lateral ones transfixing the margins of the wound. On the second day the evacuation from the bowels contained traces of blood. Animal killed

18 days after operation. Abdominal wound completely healed. Omentum adherent to wound. Numerous adhesions between the intestinal folds. Proximal blind end of ileum had been changed into a pouch-like form and contained a mass of hair and fragments of bone. One very sharp spiculum of bone had nearly perforated the intestine. New opening corresponds in size to the lumen of the ileum.

REMARKS.—The operations of lateral apposition of ileum to colon by perforated approximation discs, have shown that it is unsafe to rely upon catgut as a suturing material, as when fine catgut is used coaptation is not maintained for a sufficient length of time for adhesions to take place, and coarse catgut when tied interferes with accurate approximation, as the knots after tying mechanically separate the serous surfaces. It is advisable to use removable plates and to tie with silk. The results of ileo-colostomy made by approximation discs have not been as favorable as after jejunio-ileostomy or ileo-ileostomy, and in repeating the operation on man it would be indicated after bringing the intestines in apposition by tying the four sutures to apply a number of superficial sutures for the purpose of still further guarding against the escape of gas or fluid contents into the peritoneal cavity. The plates when properly fixed in their places and tied together with sufficient firmness not only coaptate an extensive area of serous surfaces, but they at the same time secure perfect rest for the parts which it is intended to unite, until firm adhesions have formed.

ILEO-RECTOSTOMY.

In cases of intestinal obstruction due to inoperable conditions low down in the colon it becomes necessary to establish an intestinal anastomosis between the ileum and the rectum, in order to avert the necessity of making an artificial anus, in other words, to make an ileo-rectostomy. The operation can be made in the same way as establishing a communication between the ileum and the colon by lateral implantation, by lateral apposition and double suturing or by lateral apposition by perforated decalcified bone plates. The operation is however more difficult because the rectum is not as accessible as the colon, and from the greater vascularity of the gut the in-

incision is more liable to give rise to troublesome hæmorrhage. While the slight hæmorrhage from an incision into the small intestines and the colon is usually promptly arrested by suturing or compression by the approximation discs, the bleeding from a wound of the upper portion of the rectum not infrequently requires the application of one or more catgut ligatures before it is safe to unite the wounds. During the operation traction must be made upon the rectum in an upward direction so as to lift the upper portion of the bowel out of the pelvis. In both of the experiments described below, the wounds were united by Czerny-Lembert sutures.

Experiment 88.—Dog, weight 90 pounds. Invagination of colon into colon for two inches and suturing of intussusceptum to neck of intussusciens by four fine silk sutures to prevent spontaneous disinvagination. Ileum incised in a parallel direction for an inch and a half on convex side and this wound united with a similar incision in the rectum on its anterior surface by a double row of sutures. For the purpose of immobilizing the sutured intestines an additional fine catgut suture was applied above and below the place of suturing, embracing only the peritoneal and muscular coats of the intestines. On the third, fourth, and fifth days the fæcal discharges contained blood and mucus. On the sixth day the abdominal wound partially opened, and a considerable quantity of sero-purulent fluid escaped. Death seven days after operation. Abdominal wound not united. Diffuse purulent peritonitis. Numerous intestinal adhesions. Invagination retained; adhesions between the intussusceptum and intussusciens; no gangrene; perforation at point of operation.

Experiment 89.—Cat, weight 7 pounds. Ileo-rectostomy by lateral implantation. The ileum was cut across transversely an inch above the ileo-cæcal valve, and the distal end closed by invagination, and three stitches of the continued suture. The proximal end was transplanted into a longitudinal incision on the anterior surface of the upper portion of the rectum by Czerny-Lembert suture. With the exception of an occasional slight rise in temperature no serious disturbances were observed during the progress of the case. The evacuation of the small intestines directly into the rectum appeared to increase the peristaltic action of the rectum as the fæcal discharges were fluid and frequent. Animal killed 20 days after operation. Abdominal wound completely united. No peritonitis. A few folds of the small intestines and the omentum adherent to the wound. Insertion of

ileum into rectum in an oblique direction ; union at point of junction complete throughout ; intestinal coats at this point somewhat thickened. Peritoneal surface smooth and continuous from one bowel to the other. New ileo-rectal opening corresponds in size to the lumen of the ileum ; margins of this opening consist of a ridge of mucous membrane to which a row of the deep sutures remain attached. Excluded portion of large intestine empty and contracted. Rectum contained a small quantity of fluid fæces.

5. COLO-RECTOSTOMY.

Among the many possibilities in the operative treatment of intestinal obstruction a condition might be met with where the seat of obstruction is located low down in the colon, perhaps in the sigmoid flexure, and where it might be impossible or impracticable to remove the cause of obstruction, and where it becomes necessary to restore the continuity of the intestinal canal by establishing a communication between the permeable portion of the colon and the rectum. Such an anastomosis can be made as in ileo-colostomy by lateral implantation, lateral apposition by perforated approximation plates or by double suturing. For want of time only one experiment was made, and although the animal died of the immediate effects of the operation the local conditions at the site of operation found after death show that colo-rectostomy in selected cases is not only a justifiable and feasible operation, but whenever it can be done, it is always preferable to the formation of an artificial anus. As the operation by lateral apposition requires much less time than lateral implantation, it should be preferred to the latter procedure, and should be done by perforated approximation discs and a few superficial sutures.

Experiment 90.—Medium-sized cat. Incision through the linea alba; colon cut transversely in the middle third and the distal portion, and the rectum cleared of its contents by injecting a stream of warm water from the cut end downward, a procedure which could only be well accomplished after forcible dilatation of the sphincter ani muscles. The distal end was closed in the usual manner. The rectum was drawn upward and an incision made into its anterior wall large enough to correspond with the lumen of the colon, Into this opening the proximal end of the colon was implanted by two rows of sutures. During the latter part of the operation, which lasted over an hour, the animal was seized by convulsions which continued for several hours, and finally subsided under the administration of whiskey given hypodermatically. The symptoms of shock, however, continued and death occurred 36 hours after operation. Numerous omental adhesions; closed end of bowel congested; peritoneal surfaces adherent; colon and rectum at point of implantation adherent.

REMARKS.—In cases where the obstruction is located some distance from the rectum where it would be impossible to approximate the permeable portion of the colon with the rectum, the entire colon must be excluded and the continuity of the intestinal canal restored by ileo-colostomy or ileo-rectostomy. In all cases of intestinal anastomosis where the communication is made in the lower portion of the colon or the rectum, the sphincters of the anus should be rendered temporarily incompetent by stretching for the purpose of guarding against overdistention of this part of the bowel during the time required for the healing process between the united intestines.

ADHESION EXPERIMENTS.

In works on abdominal surgery we invariably meet with the assertion that serous surfaces brought into apposition by suturing unite after a few hours. Isolated experiments and the results of post-mortem examinations have given rise to the general belief that serous surfaces so united will become firmly adherent in a very short time; but the question concerning the exact time for adhesion to take place, and for the definitive healing to be complete, can only be determined by experiments made for this special purpose. The following experi-

ments were made with a view of ascertaining the exact time which is requisite for adhesions and definitive healing between approximated serous surfaces to take place, and likewise to study the effects of local conditions which would hasten or retard these processes. It is quite important to make a distinction between the terms "adhesion" and "healing." Adhesion precedes the process of definitive healing, but implies simply the presence of an adhesive or cement substance between the serous surfaces, which mechanically agglutinates the parts, while definitive healing includes all the processes which take place during cicatrization. In intestinal surgery this distinction has an important practical bearing, as perforation may take place as long as the serous surfaces are simply held together by adhesions, while such an occurrence is beyond the reach of all possibilities after the approximated surfaces have become united by living organized tissue. Adhesions between serous surfaces take place by the exudation of plastic lymph, which acts the part of a cement material; while on the other hand the process of definitive healing is initiated by cell-proliferation from the preexisting endothelial and connective tissue cells, and the formation of a network of new blood vessels springing from each of the coaptated granulating surfaces. The processes are the same as we observe within blood vessels during cicatrization after ligature. In suturing an intestinal wound, or in making a circular enterorrhaphy, it has always heretofore been deemed necessary not to injure the peritoneum unnecessarily, for fear that such injuries would result deleteriously by interfering with the prompt union between the sutured surfaces. It is a well known fact in surgery that approximation of intact serous surfaces does not result in the formation of adhesions. When the surgeon desires to secure union between serous surfaces he resorts to mechanical or chemical irritation for the purpose of inducing a circumscribed plastic peritonitis, which invariably results in adhesions and the obliteration of the serous space. Reasoning from this analogy, I was induced to study the effects of traumatic and chemical irritation in hastening adhesions and cicatrization between apposed serous surfaces. In most of these experiments the se-

rous surfaces in the different operations were held in contact by perforated approximation plates, and in case artificial means were resorted to, to expedite the healing process, the fact is mentioned, and the result of such modification noted. The animals operated on were all dogs:

TIME SIX HOURS.

Experiment 91.—The ileum was divided near its middle, and both ends closed by invagination and the continued suture. Ileo-ileostomy was made at two points making two openings of communication. No suturing. Parts kept in apposition by perforated decalcified bone plates. To compare the effect of traumatic irritation of the peritoneum in the reparative process with the intact serous surface, the peritoneal surfaces at one point of operation designated as the upper were scarified with the point of a needle over an area corresponding to the size of the bone discs, the scratches being made sufficiently deep to penetrate the entire thickness of the peritoneum. The scarifications were made in a longitudinal and transverse direction mapping out the serous surfaces into small squares. Only slight oozing followed this procedure. The serous surfaces between the plates, (No 1.) where no scarification was made were found slightly adherent by a scanty deposit of plastic lymph. At No. 2, where scarification had been done, the amount of plastic lymph was greater and stained by blood and the adhesions much firmer.

TIME TWELVE HOURS.

Experiment 92.—In this experiment the bowel was not interrupted by division, but two adjacent coils of the ileum were united by making an ileo-ileostomy by perforated decalcified bone plates, plates holding the parts perfectly in apposition: a slight tumefaction of the intestinal walls has made the coaptation more secure. Coaptated serous surfaces very vascular, covered with a thin layer of plastic lymph which has agglutinated the folds of the intestine brought in contact.

Experiment 93.—Bowel not divided, but two adjoining loops of the ileum united by making a double ileo-ileostomy by perforated approximation discs, the two communicating openings about six inches apart. At one point of operation designated as No. 2, serous surfaces freely scarified. At both points the adhesions were perfect throughout, but where scarification was made they were notably firmer.

Experiment 94.—In this experiment a gastro-enterostomy and an

ileo-ileostomy were made at the same time and on the same animal. In both operations the parts were coaptated by perforated decalcified bone plates. Scarification of peritoneal surfaces at both places. The adhesions between the anterior surface of the stomach and upper portion of jejunum were uniform throughout, over the whole surface, kept in contact by the plates. There was no leakage on distending the stomach and intestine forcibly by water. The adhesions between the folds of the ileum at point of approximation were, if anything, firmer than between stomach and jejunum. The decalcified bone plate in the interior of the stomach was softened more than those in the intestine.

TIME EIGHTEEN HOURS.

Experiment 95.—Gastro-enterostomy by perforated decalcified bone plates: communication made between stomach and upper portion of jejunum: no scarification. Agglutination quite firm, so that forcible distention of stomach and bowel causes no leakage. New opening sufficiently large to admit middle finger and apparently lined throughout by mucous membrane. Plate in stomach very much softened and on the verge of becoming detached. On forcibly separating the adhesions the serous surfaces are found to be cemented together by a thin layer of plastic lymph, and after scraping this away they appear vascular, rough, as though completely deprived of the endothelial covering.

TIME TWENTY-FOUR HOURS.

Experiment 96.—Triple ileo-ileostomy without division of the bowel; the operations were numbered 1, 2, 3, respectively. Coaptation by approximation discs of decalcified bone. Communicating openings about six inches apart. In No. 1 no scarification. No. 2 scarification of one loop only. No. 3, scarification of both serous surfaces. After 24 hours the result was as follows:

1. Lymph scanty; adhesions not very firm.
2. Lymph more plentiful; adhesions firmer.
3. Lymph more abundant than in No. 2, and mixed with a fine stratum of coagulated blood; adhesions also firmer. The adhesions increase in firmness in the order 1, 2, 3.

Experiment 97.—Double gastro-enterostomy by perforated decalcified bone plates. The communicating openings, one near the pyloric, and the other near cardiac extremity of the stomach, were made be-

tween the anterior surface of the stomach, and the upper portion of the jejunum. In operation No. 1, near the pylorus the intact serous surfaces were brought in contact, while in the second operation both the stomach and bowel were scarified. At the post-mortem, it was found that the adhesions at both places were of sufficient firmness to prevent leakage under pressure. In No. 2 adhesions firmer and the inflammatory infiltration more marked than in No. 1. Plates in stomach much softened, but remain in situ. Openings lined throughout by mucous membrane and sufficiently large to admit the index finger.

Experiment 98.—Ileo-colostomy by lateral apposition and fixation by perforated approximation discs. Lower portion of ileum united with the ascending colon. No scarification; bowels lightly agglutinated throughout, by a very thin layer of plastic lymph; adhesions, however, can be easily separated, and where this is done the peritoneal surface appears denuded of endothelial cells, and very vascular with new vessels along the outer margin of the surface of approximation.

TIME FORTY-EIGHT HOURS.

Experiment 99.—Double gastro-enterostomy. The communicating openings were between the anterior surface of the stomach and the duodenum, and the posterior surface of the stomach and the upper portion of the jejunum. In the posterior operation the intact serous surfaces were brought in contact, while in the anterior the peritoneal surfaces of the stomach and duodenum were scarified. In both operations perforated decalcified bone plates were used. Adhesions between posterior surface of stomach and bowel uniform throughout, but easily broken down; the peritoneal surfaces injected and apparently deprived of their endothelial covering. The anterior operation has resulted in the formation of firm adhesions, the products of exudation and tissue proliferation being supplied with new vessels, the circumscribed plastic peritonitis being much more advanced than at the site of the posterior operation.

Experiment 100.—Double ileo-colostomy by perforated approximation plates. The anastomosis between the lower portion of the ileum and the colon just above the cæcum was made without scarification, while in the second operation about six inches higher up in the colon and ileum both serous surfaces were freely scarified. Omentum adherent at point of operation. Plates swollen, softened and pliable, but still efficient in maintaining coaptation and fixation. Adhesions at both places quite firm, but more so in the upper portion where scarification had been done.

Experiment 101.—Ileo-colostomy by approximation discs. The ileum was divided a few inches above the iléo-cæcal region and both ends closed by invagination, and three stitches of the continued suture. An anastomosis was made between the proximal end and the ascending colon by lateral apposition. No scarification. Intestines agglutinated at point of operation, but the adhesions gave away when the bowel was forcibly distended under hydrant pressure.

7. CHEMICAL IRRITATION OF SEROUS SURFACES.

In these experiments it was aimed to study the effect of chemical irritation of the peritoneum in the reparative process after intestinal operations. Iodine has been used for a long time in producing plastic inflammation of serous surfaces for the purpose of obliterating serous cavities, consequently this substance was used in the first experiments. To study the effects of the diffuse application of tincture of iron to the intact peritoneal cavity the following experiments were made.

8. INJECTION OF CHEMICAL IRRITANTS INTO THE PERITONEAL CAVITY.

Experiment 102.—Medium-sized dog. The needle of a hypodermic syringe was thoroughly disinfected, and a drachm of the tincture of iodine injected into the peritoneal cavity. Immediately after the injection the animal evinced great pain, which, however, appeared to subside after a short time, and subsequently no unfavorable symptoms were observed. Three days after the injection the urine was examined and showed the presence of iodine. Dog killed nine days after the injection. Circumscribed plastic peritonitis over a space four inches square, corresponding to the point where the puncture was made. At this place the omentum was much thickened, very vascular and adherent to the parietal peritoneum and the adjoining folds of the intestines.

Experiment 103.—Medium-sized dog. A fluid drachm of the tincture of muriate of iron was thrown into the peritoneal cavity by means of a well-disinfected hypodermic syringe. The pain immediately after the injection was intense, and the animal appeared to be very ill two days after the injection, and died with well marked symptoms of peritonitis on the sixth day. Diffuse plastic peritonitis was found to be the cause of death. The omentum was adherent everywhere, and the intestines were matted together by numerous adhesions. The abdominal cavity contained a considerable quantity of serous fluid.

REMARKS.—Both experiments prove that when tincture of iodine and tincture of iron are brought in contact with the peritoneum a plastic inflammation ensues, and it was reasonable to expect that if either of these substances could be applied to the serous surfaces which it was intended to unite, the reparative process would be hastened.

Experiment 104.—Triple ileo-ileostomy by perforated decalcified bone plates. Three internal fistulæ were made between the adjacent loops of the ileum about six inches apart. In operation No. 1 approximation of intact serous surfaces: in operation No. 2 the serous surfaces were painted with tincture of iron over an area corresponding to the size of the plates. In operation No. 3, the serous surfaces over the same extent were brushed with pure tincture of iodine. The animal was killed 48 hours after operation, and the following conditions were noted: No general peritonitis. All the plates firmly in place coapating the serous surfaces accurately, the swelling of the tunics of the bowel only serving to enhance their efficiency. At No. 1 adhesions quite firm, flexion of bowel and marked injection of serous surfaces. At No. 2 no adhesions between serous surfaces. The peritoneal surfaces to which the tincture of iron had been applied appeared stained, almost black, and at some points the serous coat was destroyed. At No. 3 peritoneal surfaces stained dark brown; adhesions firm, and an abundance of plastic lymph even beyond the margin of the plates.

Experiment 105.—Double ileo-ileostomy by approximation plates and omental grafting. Operation No. 1, approximation of ileum to ileum by perforated decalcified bone plates, serous surfaces intact. Operation No. 2, similar operation six inches higher up uniting the same loops, but painting the serous surfaces with pure tincture of iodine. Operation 3. Cut off a piece of omentum 2 inches wide and sufficiently long to encircle the entire bowel. After scarifying the bowel, and the omental graft on one side, the scarified surfaces were brought in contact, and the graft fixed in its place by two fine catgut sutures passed through the mesentery and both ends of the graft. Animal killed 48 hours after operation. All plates firmly in place. At No. 1, adhesions firm. At No. 2, dark-brown discoloration of surface to which the iodine had been applied, agglutination over the whole surface. Under hydrostatic pressure the adhesions first gave way between the two plates where the iodine had been applied, showing conclusively that chemical irritation of serous surfaces does not hasten the adhesive process, while it may, and probably does, expedite the

definitive healing. At No. 3, omental graft firmly adherent to the entire circumference of the bowel and beginning vascularization of the graft around its margins.

REMARKS.—In all of these experiments the post mortem examinations showed no evidences of diffuse peritonitis. In most of the cases the inflammatory process was limited to the portion of the bowel interposed between the plates. Without exception the adhesions formed were firmest and the definitive healing was initiated first where scarification was performed, results which clearly demonstrate the fact that the reparative process between serous surfaces which it is intended to unite is hastened by traumatic irritation. Traumatic irritation by scarification of the peritoneal surface with the point of an aseptic needle, is the most potent means to provoke a circumscribed plastic peritonitis, and is followed within a few hours by a copious exudation of plastic lymph, which like a cement substance, mechanically agglutinates the coaptated serous surfaces. The same measure by destroying the continuity of the non-vascular layer of the peritoneum brings at once in contact the vascular network of both sides of the bowel, and opens up a direct route for the new vessels, an important element in the rapid healing of the visceral wounds. Chemical irritants by destroying the endothelial layer of the peritoneum rather retard, than favor, early adhesion and union between the coaptated bowels, and should therefore not be resorted to in intestinal surgery with a view to hasten the reparative process.

9. OMENTAL GRAFTING.

Under the head of circular enterorrhaphy mention is made of transplantation of omental flaps after uniting the two ends of the bowel by suturing or invagination with a view of securing an additional safeguard against perforation during the process of repair. A number of experiments are described where the procedure was practised with satisfactory results. After a few days the omental flaps were found firmly adherent and vascular around the whole circumference of the bowel constituting a ring of living tissue outside the line of suturing. In

all these cases the proximal end of the flap remained in connection with the omentum, and care was taken to cut the flap in such a manner that some vessel of considerable size should furnish the necessary vascular supply. I was well aware that plausible objections could be entered against this method in that the connecting bridge between the bowel and the omentum might become subsequently a cause of intestinal obstruction by making traction upon the bowel, thus causing a flexion, or, by becoming a band of constriction for some loop of intestine. For the purpose of obviating such remote consequences I resorted to another procedure which I have designated as omental grafting. I was familiar with the fact that implantations of aseptic substances into the peritoneal cavity had frequently been done without any immediate or remote ill effects, and I had every reason to expect that a large, completely detached aseptic omental graft, in an aseptic abdominal cavity, would be well tolerated, and would soon become adherent to the subjacent peritoneal surface, and thus afford an additional safeguard against perforation and the disastrous consecutive result—perforative peritonitis during the time required for the healing of the intestinal wound. In the following experiments the grafts used were from one and a half to two inches in width, and of sufficient length to completely encircle the bowel. The free ends were made to project a few lines beyond the mesenteric attachment, and were fixed by two fine catgut sutures, each of which embraced the corresponding angles of the graft and the mesentery. The stitches were made in the direction of the mesenteric vessels, so that in tying, no vessel should be included in the suture. In these experiments dogs were used exclusively.

Experiment 106.—Three pieces of omentum, two inches wide and sufficiently long to encircle the bowel, were completely detached and grafted as follows :

1. Graft simply laid over the bowel corresponding to the lower portion of the ileum and fastened in its place on mesenteric side by two fine catgut sutures.
2. Serous surface of bowel about 6 inches higher up scarified and graft applied to this surface and fixed in the same manner.

3. About six inches still higher up bowel treated in the same way, and one of the serous surfaces of the graft also freely scarified.

The graft was scarified on the side which was to be brought in contact with the bowel. Fixation of graft by two catgut sutures on mesenteric side. Animal killed 36 hours after operation. All the grafts adherent, slightly contracting the bowel at the three different places. On separating the adhesions the subjacent serous surface very vascular and denuded of its endothelial layer. Firmness of adhesions increases in proportion to the extent of scarification done, being least firm at No. 1, firmer at No. 2, and firmest at No. 3, where both coaptated serous surfaces had been scarified. At No. 2 and 3 the plastic lymph was freely supplied with new blood vessels. The vascularization was most conspicuous on the mesenteric side.

Experiment 107.—Two omental grafts planted around the ileum in the same manner as described above. At No. 1 both the bowel and the inner side of the graft were scarified; at No. 2, only the serous surface of the bowel. Animal killed 43 hours after operation. Stump of omentum adherent to abdominal wound and intestines. No peritonitis. At No. 1, graft firmly adherent over the entire extent. A slight extravasation of blood between the graft and the bowel. Beginning vascularization of interposed plastic lymph. At No. 2 also firm adhesions and beginning vascularization of the plastic exudation. Both of the grafts appear to be stained with the coloring material of the blood.

Experiment 108.—Planting of two omental grafts around the ileum about 8 inches apart. At No. 1 both the bowel and one side of the omental graft were scarified. At No. 2 only the serous surface of the bowel was treated in this manner. Animal killed six days after the operation. Both grafts firmly adherent throughout and freely supplied with blood vessels, the largest of the new vessels being on the mesenteric side. The omental stump adherent to the portion of bowel between the grafts where a flexion has been made from this cause.

Experiment 109.—In this experiment omental grafting was done at two points around the lower portion of the ileum. At one point the serous surfaces were left intact, at the other both the peritoneal surface of the bowel and the omental graft were freely scarified. Animal remained perfectly well and was killed 8 days after operation. No signs of peritonitis. Both grafts formed a thin vascular layer around the entire circumference of the bowel and firmly and evenly united throughout. Vascularization was more marked where scarification had been

done. On attempting to separate the grafts it was difficult to find and define the line of union between the omentum and the underlying bowel as the union was very intimate and firm.

REMARKS.—In all of these experiments the grafts retained their vitality, and in a few hours became firmly adherent to the intestinal surface with which they had been brought in contact. Scarification of the serous surface has also been found in these experiments an exceedingly valuable measure in hastening the process of adhesion, granulation and vascularization. By planting grafts side by side, with and without scarification, I was enabled to determine with accuracy the beneficial influence exerted by this procedure in favoring the reparative process, and without a single exception observed that where scarification was done the adhesions were firmer and vascularization more advanced. The post-mortem examinations appeared to demonstrate that the firmness of the adhesions and the degree of vascularization were in direct proportion to the extent of traumatic irritation of the peritoneum, being always most marked in cases where both the bowel and the under surface of the graft were scarified, and least where intact peritoneal surfaces were brought into apposition. As soon as the omental grafts were cut off from the omentum they were placed in a 1:2000 solution of corrosive sublimate, kept at the temperature of the body in order to secure for the graft a perfectly aseptic condition, until everything was in readiness for the transfer of the graft to its new location. Before planting the graft it was carefully dried by pressing it between gauze or sponges wrung out of the same solution. The scarifications of the serous surfaces should only be made sufficiently deep to give rise to a very slight oozing, as when hemorrhage is more profuse there is danger of the formation of a clot between the graft and the bowel, which, if it does not ultimately prevent union between the coaptated surfaces, must necessarily interfere with the formation of early and firm adhesions. Omental grafting cannot fail in becoming an established procedure in many abdominal operations. After suturing a large wound of the stomach or intestines, a strip of omentum should be laid over the wound and fasted in its place by a few catgut sutures. After circular

enterorrhaphy the operation should be finished by covering the circular wound by an omental graft about two inches wide, which should be fixed in its place by two catgut sutures passed through both ends of the graft and the mesentery. Omental grafting should also be resorted to in repairing peritoneal defects in visceral injuries of the abdominal organs, and in covering large stumps after ovariectomy or hysterectomy, where the pedicle is treated by the intra-abdominal method.

V. CONCLUSIONS.

In conclusion I beg leave to submit the following propositions for further discussion :

1. Traumatic stenosis from partial enterectomy and longitudinal suturing of the wound becomes a source of danger from obstruction or perforation in all cases where the lumen of the bowel is reduced more than one-half in size.

2. Longitudinal suturing of wounds on the mesenteric side of the intestine should never be practised, as such a procedure is invariably followed by gangrene and perforation by intercepting the vascular supply to the portion of bowel which corresponds to the mesenteric defect.

3. The immediate cause of gangrene in circular constriction of a loop of intestine is due to obstruction of the venous circulation, and takes place first in the majority of cases at a point most remote from the cause of the obstruction.

4. On the convex surface of the bowel a defect an inch in width, from injury or operation, can be closed by transverse suturing without causing obstruction by flexion. In such cases the stenosis is subsequently corrected by a compensating bulging, or dilatation of the mesenteric side of the bowel.

5. Closing a wound of such dimensions on the mesenteric side of the bowel by transverse suturing may give rise to intestinal obstruction by flexion, and to gangrene and perforation by seriously impairing the arterial supply to, and venous return from, the portion of bowel corresponding with the mesenteric defect.

6. Flexion caused by inflammatory and other extrinsic

causes gives rise to intestinal obstruction only in case the functional capacity of the flexed portion of the bowel has been impaired or suspended by the causes which have produced the flexion, or, by subsequent pathological conditions which have occurred independently of the flexion.

7. As in flexion, a volvulus gives rise to symptoms of obstruction when the causes which have given rise to a rotation upon its axis of a loop of bowel, have at the same time produced an impairment or suspension of peristalsis in the portion of bowel which constitutes the volvulus, or when a diminution or suspension of peristalsis follows in consequence of the degree or extent of the rotation.

8. Accumulation of intestinal contents above the seat of invagination is one of the most important factors which prevents spontaneous reduction, and which determines gangrene of the intussusceptum and perforation of the bowel.

9. Spontaneous disinvagination is not more frequent in ascending than descending invagination.

10. The immediate or direct cause of gangrene of the intussusceptum is obstruction to the return of venous blood by constriction at the neck of the intussusciptions.

11. Ileo-cæcal invagination, when recent, can frequently be reduced by distention of the colon and rectum with water, but this method of reduction must be practised with the greatest caution and gentleness, as over-distention of the colon and rectum is productive of multiple longitudinal lacerations of the peritoneal coat, an accident which is followed by the gravest consequences.

12. The competency of the ileo-cæcal valve can only be overcome by over-distention of the cæcum, and is effected by a mechanical separation of the margins of the valve, consequently it is imprudent to attempt the treatment of intestinal obstruction beyond the ileo-cæcal region by injections per rectum.

13. Resection of more than six feet of the small intestine in dogs is uniformly fatal, the cause of death in such cases is always attributable to the immediate effects of the trauma.

14. Resection of more than four feet of the small intestine

in dogs is incompatible with normal digestion, absorption and nutrition, and often results in death from marasmus.

15. In cases of extensive intestinal resection the remaining portion of the intestinal tract undergoes compensatory hypertrophy which macroscopically is apparent by thickening of the intestinal coats and increased vascularization.

16. Physiological exclusion of an extensive portion of the intestinal tract does not impair digestion, absorption and nutrition as seriously as the removal of a similar portion by resection.

17. Faecal accumulation does not take place in the excluded portion of the intestinal canal.

18. The excluded portion of the bowel undergoes progressive atrophy.

19. A modification of Jobert's invagination suture by lining the intussusceptum with a thin flexible rubber ring, and the substitution of catgut for silk sutures is preferable to circular enterorrhaphy by the Czerny-Lembert suture.

20. The line of suturing, or neck of intussusciptions, should be covered by a flap or graft of omentum in all cases of circular resection, as this procedure furnishes an additional protection against perforation.

21. In circular enterorrhaphy the continuity of the peritoneal surface of the ends of the bowel to be united should be procured where the mesentery is detached by uniting the peritoneum with a fine catgut suture before the bowel is sutured, as this modification of the ordinary method furnishes a better security against perforation on the mesenteric side.

22. In cases of complete division of an intestine, if it is deemed advisable not to resort to circular enterorrhaphy, one or both ends of the bowel should be closed by invagination to the depth of an inch, and three stitches of the continued suture embracing only the peritoneal and muscular coats.

23. The formation of a fistulous communication between the bowel above and below the seat of the obstruction should take the place of resection and circular enterorrhaphy in all cases where it is impossible or impracticable to remove the cause of obstruction, or, where after excision it would be impossible to restore the continuity of the intestinal canal by su-

turing, or where the pathological conditions which gave rise to the obstruction do not constitute an intrinsic source of danger,

24. The formation of an artificial anus in the treatment of intestinal obstruction should only be practised in cases where continuity of the intestinal canal cannot be restored by making an intestinal anastomosis.

25. Gastro-enterostomy, jejunio-ileostomy and ileo-ileostomy should always be made by lateral apposition with partially or completely decalcified perforated bone plates.

26. In making an intestinal anastomosis for obstruction in the cæcum, or colon, the communication above and below the seat of obstruction can be established by lateral apposition with perforated approximation plates, or by lateral implantation of the ileum into the colon or rectum.

27. An ileo-colostomy, or ileo-rectostomy by approximation with decalcified, perforated bone plates, or by lateral implantation should be done in all cases of irreducible ileo-cæcal invagination, where the local signs do not indicate the existence of gangrene or impending perforation.

28. In all cases of impending gangrene or perforation, the invaginated portion should be excised, both ends of the bowel permanently closed, and the continuity of the intestinal canal restored by making an ileo-colostomy or ileo-rectostomy.

29. The restoration of the continuity of the intestinal canal by perforated approximation plates, or by lateral implantation, should be resorted to in all cases where circular enterorrhaphy is impossible on account of the difference in size of the lumina of the two ends of the bowel.

30. In cases of multiple gunshot wounds of the intestines involving the lateral or convex side of the bowel, the formation of intestinal anastomosis by perforated decalcified bone plates should be preferred to suturing, as this procedure is equally, if not more, safe, and requires less time.

31. Definitive healing of the intestinal wound is only initiated after the formation of a network of new vessels in the product of tissue proliferation from the approximated serous surfaces.

32. Under favorable circumstances quite firm adhesions are found within the peritoneal surfaces in six to twelve hours

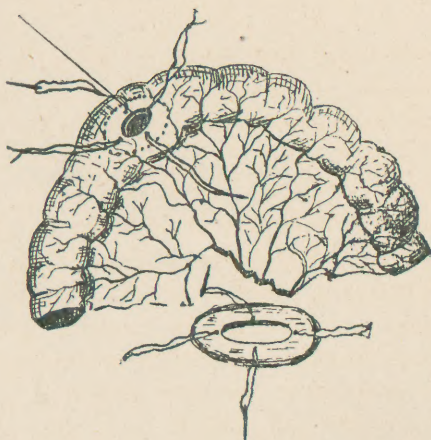
which effectually resist the pressure from within outward.

33. Scarification of the peritoneum at the seat of coaptation hastens the formation of adhesions and the definitive healing of the intestinal wound.

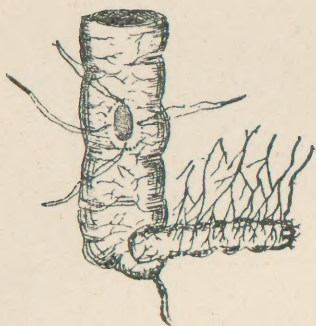
34. Omental grafts, from one to two inches in width, and sufficiently long to completely encircle the bowel, retain their vitality, become firmly adherent in from 12 to 18 hours, and are freely supplied with blood vessels in from 18 to 48 hours.

35. Omental transplantation, or omental grafting, should be done in every circular resection, or suturing of large wounds of the stomach or intestines, as this procedure favors healing of the visceral wound, and affords an additional protection against perforation.

Plate within the intestine above seat of obstruction.



Perforated decalcified bone plate.

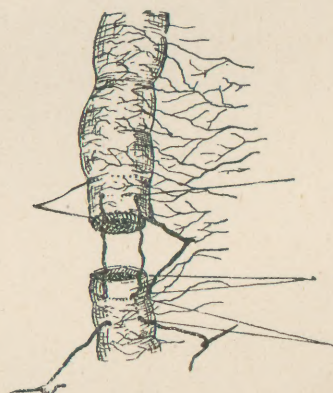


INTESTINAL ANASTOMOSIS BY PERFORATED DECALCIFIED BONE-PLATES.

Plate within colon below seat of obstruction.

Approximation of intestine by tying of sutures.

Rubber ring within bowel fixed by continuous catgut sutures.



Needles passed from within outward through entire wall of bowel and ring.

Part to be invaginated.

Needles passed through serous and muscular coats.

AUTHOR'S MODIFICATION OF JOBERT'S SUTURE.

PLATE. I—METHODS OF INTESTINAL ANASTOMOSIS.

